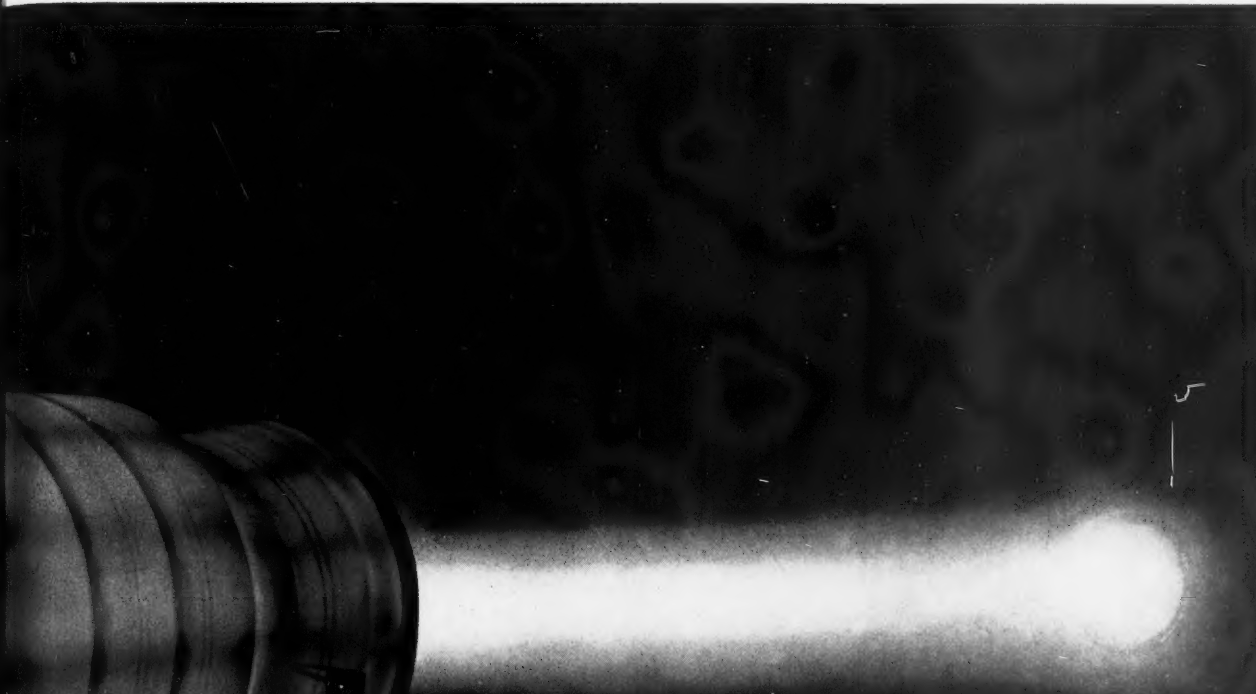
Astronautics

A PUBLICATION OF THE AMERICAN ROCKET SOCIETY

APRIL 1959



SPECIAL RAMJET SECTION

Astronautics

A PUBLICATION OF THE AMERICAN ROCKET SOCIETY, INC.

April 1959 volume 4 number 4
PART 1 OF 2 PARTS

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Print run this issue, Part I: 20,217

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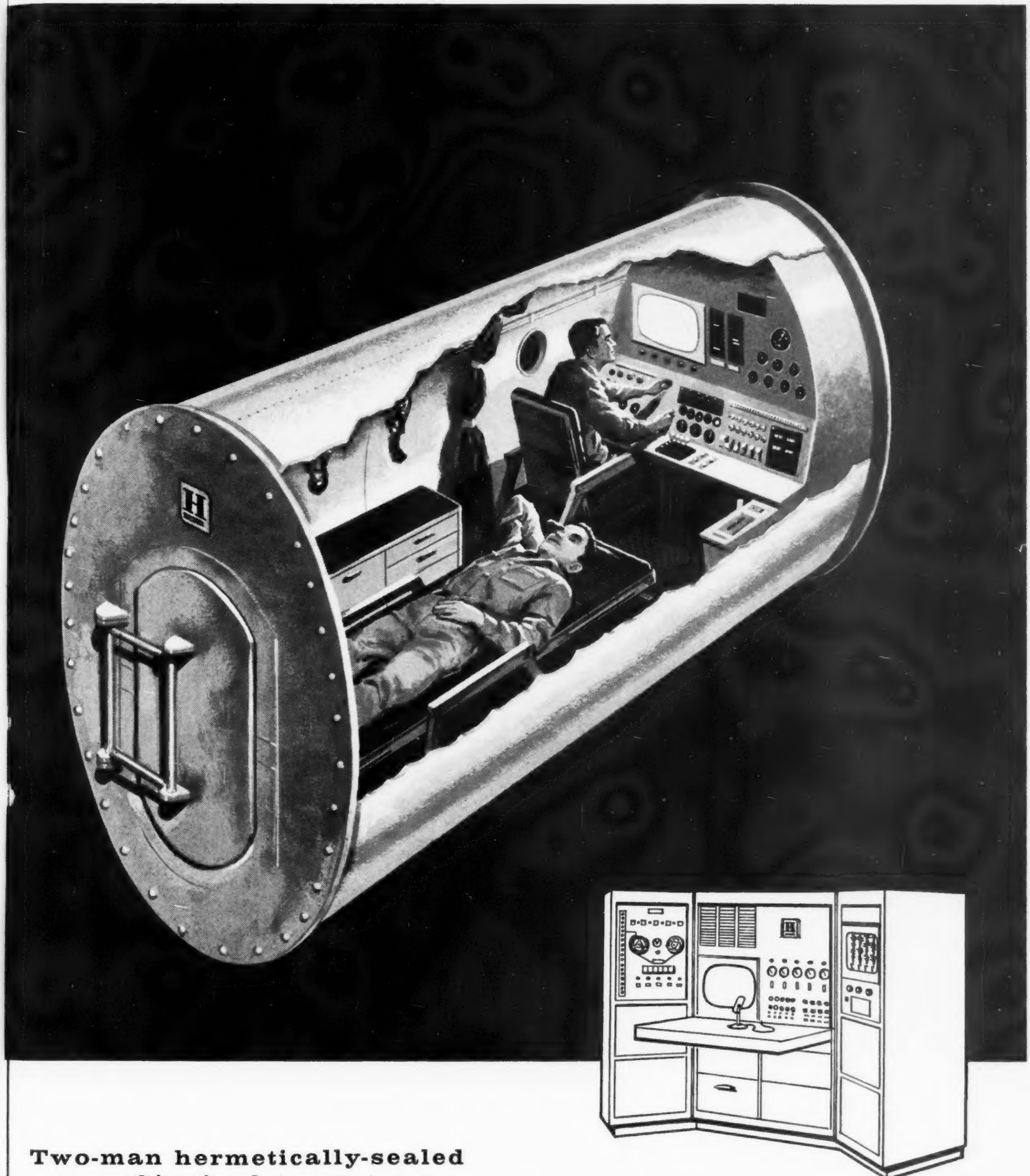

Astro notes

ASTRONAUTICS

• Pioneer IV, launched March 3 from Cape Canaveral, brought crowning success to the series of moon probes begun last August by NASA, and showed the technical class and polish of NASA's direction of the rapidly growing U.S. space program. Boosted to escape velocity by a Juno II propulsion system, the 13.4-lb payload of Pioneer IV coasted within roughly 37,000 miles of the moon in the late afternoon of March 4 and continued on into heliocentric orbit. JPL's tracking station at Goldstone, Calif., followed the new planet to a distance of 400,000 miles—a new record—which brought to nice coincidence the range of the Goldstone station and period of battery power (about 90 hr) for the probe's transmitters.

Pioneer IV gave nearly all the results hoped for, with its radiation detection equipment functioning perfectly. James A. Van Allen, from a quick look at data, found no evidence of radiation concentrations over the tracked course of the probe, other than the previously discovered Great Radiation Belt about the earth. Pioneer IV passed too far from the moon for its photoelectric scanner to be actuated. NASA's tracking network performed as anticipated. Only the miss distance of the probe proved a little disappointing, as it prevented measuring possible radiation peaks near the moon's surface.

• "Frozen sleep" will protect man from psychic damage in long space flights, reduce the cost of equipment to send man into deep space, and will keep man from aging biologically on long space journeys, says John Lyman of UCLA's Biotechnology Lab. According to Dr. Lyman, experiments indicate that biochemical processes continue in frozen animals even after heartbeat stops and that these processes must be stopped simultaneously if the animal is to revive successfully. Dr. Lyman believes his group has devised ways to carry out this freezing and revival.

SATELLITES

• Vanguard program, in abeyance for some time, made a spectacular re-entry with the launching of Vanguard II, the world's first weather satellite, from Cape Canaveral Feb. 17. In little more than a week, Vanguard II produced a more precise and continuous flow of data than any previous U.S. satellite. It mapped cloud cover for some two weeks with scanners developed by Perkin-Elmer for the Army Signal Labs (see page 76) and then entered an estimated decade of orbiting before it will return to earth. NASA brass again appear in a good light for taking the pressure off the Vanguard program and perhaps saving it from an early grave.

• ARPA launched Discoverer I, a Thor-Hustler satellite vehicle, into the first polar orbit from Vandenberg AFB Feb. 28, but for several days after the launching it could not be determined whether the vehicle had attained orbit. The 1300-lb satellite carried an attitude-control system operating in conjunction with an IR horizon scanner and 40 lb of telemetering equipment, including a radar beacon and transponder to facilitate long-range tracking. Difficulty in picking up the satellite has been attributed to the stabilization system, which evidently did not keep directional antennas in the expected orientation. That Discoverer I was in orbit was finally deduced from 41 separate tracking reports from eight stations on the U.S. mainland, Hawaii, and Alaska. Although communication and guidance equipment functioned adequately during launching, value of the satellite has been difficult to assess.

• Hans Bethe, submitting his opinions to the Senate Disarmament Subcommittee on an inspection system to insure the detection of nuclear-weapon tests, proposed that satellites be utilized to monitor the outer reaches of the atmosphere and nearby space.

MAN IN SPACE

• NASA Deputy Director Hugh Dryden iterated that the first orbital flight of a manned Mercury vehicle will be as routine as the engineers can make it. NASA is determined, he said, that pilots of the Mercury capsules will run no more risk than test pilots of new high-performance aircraft.

SPACE PROPULSION

• NASA staff members unveiled a comprehensive "national booster program" in testimony before the Senate space committee. The program contemplates seven new rocket vehicles, requiring the development of five new engines. The vehicles range from the low-cost Scout, with a satellite capability of 150 lb, up to the colossal Nova, a five-stage rocket standing 300 ft high and capable of orbiting 75 tons.

• Scout will be NASA's "space pickup truck." It will consist of four stages of solid propellant motors—first stage, an Aerojet Senior; second stage, an improved Thiokol Sergeant; third stage, a new scale-up of the Vanguard third stage from Allegheny Ballistics Lab; and fourth stage, an ABL third-stage Vanguard motor. (Aerojet Senior was originally developed for the joint Army-Navy IRBM program but was discarded when the Navy undertook the Polaris project.) Scout will weigh about 35,000 lb, stand 70 ft high and cost about $500,000 a copy. It will use Minneapolis-Honeywell inertial guidance and will be controlled by a combination of jet vanes in the first stage and pressure jets on the second stage. Third stage will be spin-stabilized. The system should be operational within a year.

• Probably the first of the new series of boosters to see action will be the Atlas-Able. This will consist of an Atlas ICBM mated to the modified second and third stages of the Vanguard used in the Thor-Able vehicle. Also imminent is Atlas-Hustler, which will use the Lockheed-Bell Hustler motor, which powered Discoverer I into orbit. These adaptations should be fairly easy since both of the upper-stage systems have been designed to fit the warhead adapter ring of the Thor IRBM—which is identical to that of Atlas.

• Atlas is also slated for use in two other combinations—the Vega and Centaur. Vega is a three-stage system using the Atlas, a second stage powered by GE's Vanguard engine (with tankage redesigned to match Atlas's greater diameter) and a third stage using storable liquid propellants under development by JPL. Centaur is identical to Vega, except that the second stage will be powered by a General Dynamics-Pratt & Whitney booster using liquid hydrogen and oxygen for greater I_{sp}. Vega and Centaur should orbit 3000 lb, or provide a

soft landing for 730 lb of instruments on the moon.

• Saturn and Nova are the biggest of the new boosters. Saturn (also called Juno V by the Army) will be a four-stage vehicle using eight clustered Rocketdyne motors in the first stage to develop 1.2 million lb thrust, a Titan booster of 300,000 lb thrust as the second stage, the Centaur high-energy motor as the third stage, topped by the JPL storable motor. Nova will be a five-stage rocket weighing 4.5 million lb. First stage will be a cluster of four 1.5-million-lb-thrust single-chamber motors; second will be a single 1.5-million-lb-thrust booster; third and fourth will be high-energy motors of 80,000 and 15,000 lb thrust, and the fifth will be the JPL motor.

• T. K. Glennan, NASA director, estimated the national booster program will cost U.S. taxpayers more than $2 billion. He told Congress a single launching with the 1.5-million-lb-thrust booster will cost more than $20 million. "In my opinion," he said, "this is the last time that. . .NASA will be requesting a budget of half a billion dollars. If anything, the level of our space effort today is minimal if we are to reach our goals as promptly as we must."

COMMUNICATIONS

• Readers of Andrew Haley's discussion of radio-space allocation this month and last will not be surprised to hear the President has asked Congress to authorize a thorough study of this complex problem. The plan calls for a five-member commission, named by the President, to continue investigation of the OCDM Advisory Committee on Telecommunications, which after a year of study called for more study time.

• Satellites will play a major role in the worldwide communication systems being developed independently by AF and Army. Proposals for the Army UniCom system (480 L), which will be based on the kind of delay-repeat link demonstrated with the Atlas-Score satellite, are being prepared now by contractors who attended a recent bidders conference at Army Signal Labs. Contracts are expected to be let in May for UniCom. AF has already revealed the contractors for its long-range communication planning— ITT and RCA, with ITT the senior partner—and announced an imminent $3 million contract to start studies. These two systems, covering all phases of global military communications, will begin to go into operation in the mid-1960's.

NASA

• Armed with a Vanguard II and Pioneer IV and backed by projects recently proposed to Congress (see Space Propulsion), NASA Administrator T. K. Glennan, speaking at National Press Club, diplomatically showed that the agency has built itself a solid organizational base and charted the immediate future of U.S. space projects with deliberate speed, and without sacrificing the means at hand for space research. Having mentioned that this would be the last year NASA would request of Congress appropriations of a half-billion dollars, he set down the requirements for the U.S. to come to the fore in astronautics: "For years to come, we must be prepared to invest—and in substantially large amounts—talent, treasure, and time. . . . This is a story that demands telling. . . ." NASA's progress in contracting its projects can be found in the summary tables on pages 104–105.

• One imminent NASA satellite project will be a "high apogee" satellite designed to obtain radiation data for a year or more. Reportedly scheduled for firing this month, the 325-lb satellite would be launched into a low-latitude orbit from Cape Canaveral and soar out as much as 30,000 miles before falling back to a perigee of a few hundred miles. It would carry instruments devised by James Van Allen and other leading radiation scientists to answer many questions about the nature of the particles now trapped in the earth's magnetic field.

• NASA's most venturesome project of the year may well be two attempts to reach Venus this June, when the planet comes into favorable relationship with earth. According to Rep. Overton Brooks (D., La.), NASA will attempt to launch a 78-lb probe, using a Thor-Able, and a 325-lb "orbiter" powered by an Atlas-Able. The latter will have a retro-rocket to be fired in the vicinity of Venus. Experiments aboard the probes will include a lightweight magnetometer, photon counter, photocells for close-up albedo measurements of Venus, a microwave propagation experiment, radiation counters, and other gear.

• All told, NASA expects to launch 15 satellites and space probes this year and a like number next year. To support its accelerating program, it plans to expand its tracking network with four new Minitrack stations in Alaska, the U.S., Newfoundland, and Europe for coverage of polar satellites. It will also establish two new radio-telescope dishes, similar to the Goldstone one, in Australia and South Africa, and establish a precision radar acquisition and tracking facility in southern Texas to cover midcourse re-entry and landing of the Mercury capsules.

• The *Federal Register* of March 5 carries the first of a series of discussions on NASA patent-waiver regulations. A public hearing on waiver regulation will be held May 18 in the NASA auditorium.

• NASA has issued a readable 53-page summary of its history and activities for the calendar year 1958.

SECURITY

• ARPA came under fire for its secretive handling of the Discoverer I satellite, which was plagued with communications difficulties after successfully entering orbit. It had a ready answer, however, for Allen Hynek of the Smithsonian Astrophysical Observatory when he complained that Moonwatch teams might have helped in the location of the 1300-lb satellite. Since the satellite was launched with the sun almost overhead, the plane of its orbit was necessarily in the plane of the sun and earth. This meant Discoverer was either in broad daylight or complete darkness except for fleeting instants near the poles, and hence could not be detected visually.

• ARPA also was criticized for withholding the radio frequencies of its satellite, except to a select number of military and contractor stations. While the radar transponder and the telemetry transmitter aboard the vehicle were not working, the low power vhf beacon sent out sporadic signals as the Discoverer tumbled in space. Publication of its frequency might have facilitated the tracking operation. At any rate, AF got enough reports to determine that its first satellite was tracing a 95.5-min polar orbit with an apogee of 519 miles and a perigee of 176 miles, compared with the targets of 425 and 170 miles, respectively. This meant the Thor-Hustler launching system performed perfectly.

MISSILES

• Both Aerojet-General and Thiokol

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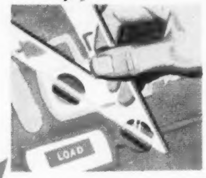
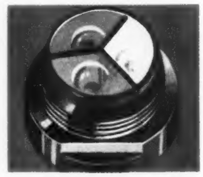


100% FLUSH PANEL . . . Eliminates protruding hardware . . . unless specified by human engineering requirements. Switching functions may be recessed, flush, or over-flush.



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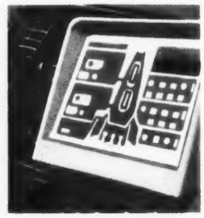
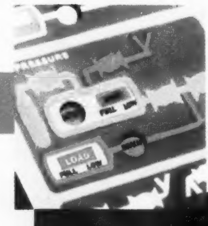


CONCENTRATED GROUPING OF CONTROLS . . . Multiple function of TRI-LITE controls permits high component density, saving from two to four times space required by ordinary panel. Permits instant visual recognition and action by operator, minimizing time-loss found in larger panels.

VERSATILE SWITCHING . . . The switching and indicating techniques are specifically designed for maximum compatibility with this advanced panel. Momentary, positive feel and alternate action switching is available.

LIMITLESS COLOR COMBINATIONS . . . The unique combination of TRILITES plus multi-color photo printing of panel allows unlimited color guidance, distinctly identifiable even by color blind.



SCHEMATIC DIAGRAMMING . . . Photo color printing of panel surface permits visual schematic diagramming. Increases speed and efficiency of operators and recognition of system indications. Reduces indoctrination period for operator training. Eliminates the written word.

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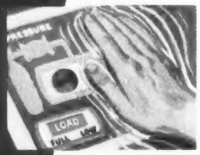
SHOCK AND ABUSE TOLERANT . . . Laminated Fiberglas panel resists chipping, shattering, crazing. Coefficient of expansion identical to aluminum sub-assemblies eliminates buckling under stress or extreme cold or heat conditions.



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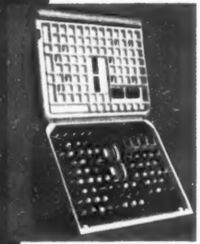

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received major AF contracts covering development of solid motors for all three stages of the Minuteman ICBM. Aerojet, with an $85 million contract, will develop motors at its Solid Rocket Plant at Sacramento, Calif. Thiokol, with a $77 million contract, will do work at its Brigham, Utah and Elkton, Md. facilities.,

• In line with the Pentagon's policy of hedging bets on vital hardware development programs, the Navy has awarded Hercules Powder Co. a contract to design a pilot line for production of an alternate double-base propellant motor for the Polaris at Indian Head, Md. Presumably, the motor would be ordered into production only if the Aerojet powerplant developed severe troubles. The Navy also announced that ABL, a Hercules' subsidiary, had successfully tested a movable molybdenum nozzle for the Polaris. This is also an alternate system, since Aerojet uses the "jetavator" control concept.

• Defense Secy. Neil McElroy, with the support of Rep. George Mahon, chairman of the House Defense Appropriations Subcommittee, fought back pressure to order a $730 million speedup in the Nike-Zeus anti-missile program. He insisted a production order would be premature because of the developmental status of the weapon. In the meantime, DOD dropped the Army's Plato project, which called for mobile anti-missile capability to support battle troops.

• Navy is reportedly installing an underwater detection system at Wake, Midway, and Kwajalein for precise calculation of the impact of ballistic missiles fired on the Pacific Missile Range. Each island will be equipped with a spoke-like network of cables extending 70 miles out to sea. This network, it is expected, will incorporate hydrophones to detect and triangulate the detonation of sofar bombs released by warheads. AF has been operating such stations for several years at Antigua, Fernando de Noronha (off Brazil), and Ascension Island in the South Atlantic.

• Teams of contractors led by Boeing and Martin Co. will complete work on their competing designs for Dynasoar in April. AF decision is expected about June. Boeing's Dynasoar might be powered by two stages of Minuteman rocket motors —five in the first stage and two in the second. Martin will use a Titan first stage and a high-energy second stage. The glide bomber would have no propulsion capability, except for a small jet engine and a tiny store of fuel to ease the landing maneuver at the end of the mission.

• Bomarc will soon be emplaced in concrete bins, rather than the present garage-type sheet metal shelters.

• Bids are in for construction of the first operational underground launching complex for Titan at Lowry AFB, Colo.

• Marquardt reports that more than 200 operational flights have been made of the RJ43 ramjet in Bomarcs, Kingfisher drones, and the X-7 test vehicle.

• Douglas has proposed use of Thor-Able as an ICBM, its main arguments being that the vehicle is reliable, that it is in production and could be delivered quickly.

• Hawk, the ground-to-air AA missile developed by Raytheon for the Army, scored a direct hit on a Lockheed Kingfisher drone traveling at Mach 2 at 35,000 ft. This was reported as the second test of Hawk against a supersonic target.

• Thiokol successfully static-fired the first developmental motors for the Army's 500-mile Pershing missile.

INDUSTRY

• AF departed from its cost-plus-fixed-fee method of contracting for the first time in granting Rocketdyne a $25 million fixed-price contract for production of Thor engines. Fixed-price contracts are intended to speed deliveries and provide contractors with an incentive to cut production costs.

• A bill (H.R. 4103) providing indemnification for manufacture of aircraft, missiles, and spacecraft has been introduced in the House. Proposed legislation would limit Government obligation to half a billion dollars for any one incident, covering all contractors concerned.

• Speaking at the Franklin Institute, H. Thomas Hallowell Jr., president of Standard Pressed Steel Co. and three-time head of the American Standards Assn., decried mounting costs of failures and repair parts for missiles and space vehicles and proposed a major national program on reliability and manufacturer standards. This program would include a national review of standards and an added $90 million for National Bureau of Standards studies of basic standards and new methods for making refined measurements in industry.

• Taking the name General Telephone and Electronics Corp., Sylvania Electric Products and General Telephone Corp. merged, with Sylvania continuing to operate as a separate company, wholly owned by GTE.

• The new company being formed by Hercules Powder and Stauffer Chemical will be able to produce more than a million pounds per year of aluminum trialkyls and other aluminum alkyls, which, it is expected, will give the boron-based fuels a run for the money.

R&D

• With Scott Crossfield in its cockpit, the X-15 went through the first preflight hop under the wing of a B-52 aircraft March 10 at Edwards AFB, Calif. Aerodynamic and system checks were made at an altitude of 38,000 ft. Crossfield and engineers in the B-52 communicated with closed-circuit TV as part of the test.

• Concerned over future U. S. defenses, ARPA is expected to let short-term study contracts this month in an effort to find some basic, long-range approaches to the anti-missile problem. The $1.5 million program, known as GLIPAR (Guide-Line Identification Program for Anti-Missile Research), will consist of six-month studies by half a dozen or more contractors of a complete defense system for the decade between 1970 and 1980, and will embrace such exotic concepts as anti-matter, anti-gravity, and radiation weapons.

• Prodded by keen U. S. military interest, American companies are currently spending about $5 million a year to develop improved thermoelectric materials. Although the Seebeck (heat to electricity) and Peltier (electricity to temperature drop) principles are more than a century old, conversion efficiencies hovered around 1 per cent until the relatively recent discovery of semiconductor materials, which are poor heat, but good electrical, conductors. Now efficiencies of 7 to 10 per cent are routine, and researchers hope to double or treble even these levels. Compact, light, non-moving thermoelectric devices are already refrigerating IR sensors in missiles, and will have important applications in providing auxiliary power for space vehicles.

• Navy is thinking of thermoelectric air-conditioning for its submarines and even thermoelectric propulsion plants for surface vessels. Ultimately, thermoelectric units may permit direct conversion of heat to electricity in nuclear reactors, eliminating costly heat exchangers and turbogenerators.

• The Palmer Physical Lab of Princeton Univ. is conducting a vigorous new investigation of the nature of gravity as a test of Einstein's theories. Princeton researchers want to investigate the equivalence of gravitational and inertial mass and the possibility that the gravitational constant may vary with the age of the universe, motion, and other factors. Experiments will include extremely sensitive torsion balances and pendulums, gravimeters capable of measuring long-term changes in terrestrial G as a function of velocity, atomic clocks using rubidium and cesium vapor which will be compared to determine motional effects on atomic constants, and comparison of an atomic clock's measure of time with a gravitational time measurement supplied by a satellite.

• Working with the AF and major aircraft companies, the MIT Servomechanisms Lab has scored an important advance in automation with its new APT system for automatically programming tools by means of numerical control. The system utilizes a digital computer to plot continuously the path of a machine tool in cutting a complex part, with consequent time savings of as much as 95 per cent, as compared with the old manual method of programming tools. AF and industry representatives agree that the system, which utilizes a simple vocabulary of 107 words, will vastly facilitate engineering changes in missile and aircraft during the flight-test stage. They were less certain about the future of highly skilled machinists and small job shops working for the industry in view of the fact that an unskilled worker can theoretically learn the APT vocabulary—and all the art of tool control—in just a few weeks time.

• USAF scientists at WADC's Aeromedical Lab have developed a special nylon couch with tubular arm suports that will permit a man to withstand an acceleration of 16 G's without blacking out. With his arms supported just over his controls by the tubing, a man can perform guidance tasks in the rig up to 14 G's.

• The Space Medicine Div. of the AF School of Aviation Medicine in San Antonio has completed work on a 15-lb "bio-pac" capable of accommodating four mice on a space journey, as well as a 57-lb package for a rhesus monkey. The latter includes a psychomotor experiment to test the monkey's "emotional equilibrium," consisting of a flashing light and a lever the simian must operate to avoid an electric shock. The packages will be fired on a "space available" basis, presumably by a recoverable Discoverer satellite, and will include a food-and-water mixture, oxygen, CO_2 absorber, ventilating fan, and even a special cooling system for re-entry. SMD scientists are also working on a 100-lb capsule for a chimpanzee.

• Pluto, the AEC project to develop a nuclear-powered ramjet engine, is progressing satisfactorily. Encouraging developments of reactor materials have been made during the past year.

• RCA's stratosphere TV system will allow astronomers on the ground to aim and focus the 12-in. reflecting telescopes to be carried aloft 15 miles by balloon this summer in a solar observation program being conducted by Princeton's Astronomy Dept. for ONR and NSF.

• A detailed study of the moon being made by the Physics Div. of Armour Research Foundation for the AF Special Weapons Center will be used in planning lunar research flights.

• Difficulty in tracking Discoverer I may be behind the reported move of Sentry firings, scheduled to begin in fall from Vandenberg AFB, to Cape Canaveral. Sentry, carrying a large video camera and command transmitting equipment, will be able to map vast areas of the earth, including all of Europe and Russia.

SPACE LAW

• The House space committee has begun hearings aimed at clarifying the issue of national sovereignty in space.

• While this committee sat in session, a radio broadcast from East Berlin voiced a Communist protest over the launching of the Discoverer satellite, claiming the satellite served "military" purposes and "carried the Cold War into space." The broadcast raised the question of the right of the U. S. to put a "military" satellite into orbit without getting permission of countries it would pass over.

MATERIALS

• Highly malleable vanadium alloys have been produced for the first time by Armour Research Foundation. The alloys, which have good weldability in sheet form, retain strength well at temperatures up to 1500 F.

• Samarium-153, a low-energy-photon source with a halflife of about two days, has been developed by GE's Research Lab. This radioisotope has potential wide applications in industrial and medical radiography.

EDUCATION

• Herbert A. Smith, president of National Teachers Assn., landed on high school teachers in testimony before the House space committee. According to Smith, about 50 per cent of the nation's secondary school teachers should be replaced at the earliest opportunity because they are not qualified to teach a modern curriculum. The association's executive secretary, Robert H. Carleton, declared in following testimony that nearly all primary and secondary school science courses entailed much the same form and content of courses taught in 1910.

• NSF made over a thousand grants totalling some $45 million during the second quarter of 1959 in support of basic research, conferences in the sciences, exchange of scientific information, and science-teacher training.

• Two six-week summer courses on technical Russian will be offered this summer by the Polytechnic Institute of Brooklyn to aid researchers who must keep abreast of U.S.S.R. literature.

• Among Pennsylvania State Univ. summer engineering seminars will be ones on missile systems engineering and underwater missile engineering early in June. The fee for missile systems is $80; the underwater missile seminar, sponsored by the Navy Dept., requires no fee but admits only those approved by the Navy BuOrd.

• Some 800 high school students attended the Army's recent "Teen-Age Rocket Seminar" at New York Univ. Paul Winternitz, NYU authority on propellants and long-time ARS member, discussed rocket fundamentals for the young enthusiasts, who also heard from experts from Picatinny Arsenal, IBM, Grumman, and Brooklyn Polytechnic.

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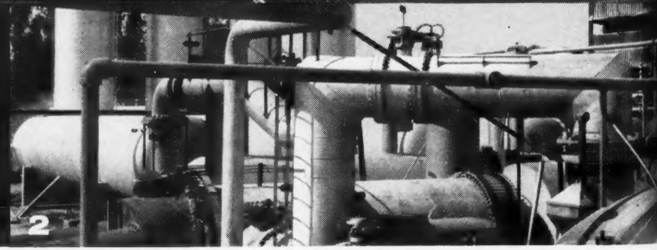

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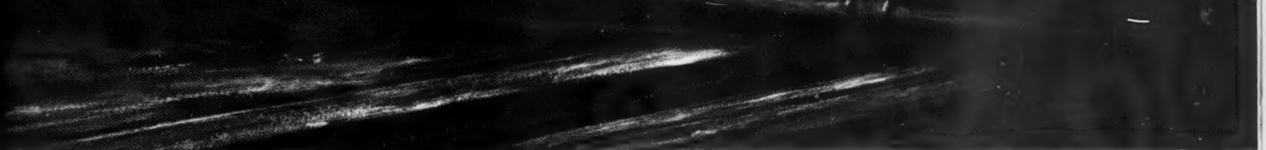
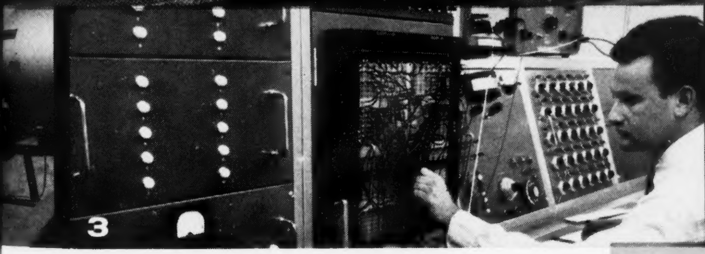
Engineers and scientists whose training and experience qualify them for responsible positions in the analysis, design, and operation of such advanced facilities will find full opportunity to demonstrate their talents at Marquardt. May I suggest you contact Mr. Floyd E. Hargiss, Manager of the Professional Personnel Department, 16547 Saticoy Street, Van Nuys, California.

Roy E. Marquardt, *President*





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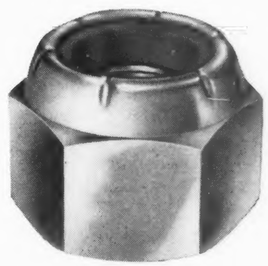

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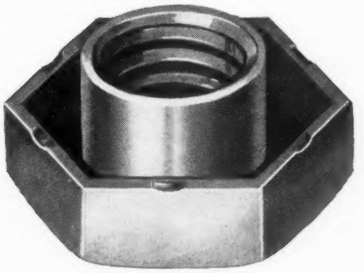

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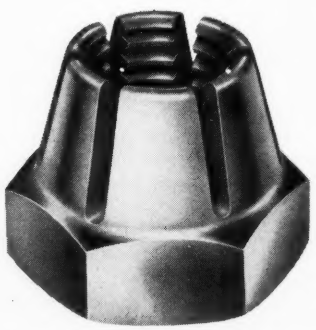

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International scene

BY ANDREW G. HALEY

Radio Allocations for Astronautics (Part 2)

Last month, we reviewed briefly some of the background for the comments filed by ARS on Jan. 26 in response to the FCC's 16th Notice of Inquiry, calling for comments on the Commission's specific proposals for Space and Earth/Space radio services, and for the allocation of certain frequency bands for such services.

Highlights of the ARS document follow:

Definitions

The Society urges that the FCC's proposed definition of "Objects in Space" be modified; that the definition of "Earth Station" be enlarged; and that an entirely new class of service be established to be known as the "Earth/Space/Earth Service," with provision for "Earth/Space/Earth Stations" to operate in the new service.

In accordance with a recommendation of Rear Adm. John E. Clark, the Society urges that the words "or space vehicles during their launching phase" be included after ". . . on the earth's surface" in the proposed definition of Objects in Space, so that the term would be defined as follows:

"*Objects in Space*—Natural or artificial objects such as the moon, planets, satellites, and space vehicles, maintaining sustained motion beyond the major portion of the earth's atmosphere. Objects in space do not include such objects as conventional aircraft, balloons, missiles or rockets which are limited to flight between points on the earth's surface, or space vehicles during their launching phase."

Adm. Clark suggests in support of this suggestion that "the interference problems in the frequency regions used during the launching phase for instrumentation purposes, which are not associated with the operating part of the satellite or space vehicle flight, can be isolated on an area basis sufficiently well to avoid serious interference problems."

On the basis of data furnished by James R. Dempsey and Krafft Ehricke, the Society proposes that the definition of "Earth Station" be revised to read as follows: "A station in the Earth/Space service located upon the earth's surface, *or on objects such as conventional aircraft, balloons, missiles, or rockets which are limited to flight between points on the earth's surface, which are engaged in a radio communication service with objects in space.*" [Italics indicate additional language proposed.]

John R. Pierce and James L. Middlebrooks raised a substantial point as to an important aspect of space communication which does not appear in the FCC proposal. Dr. Pierce stated: "There is an important field of application for satellite repeaters to provide communication between points on earth. The bands proposed are far too narrow for a useful broadband service of this sort. Many hundreds of megacycles will ultimately be required. Also, frequencies above 10,000 mc are ill-suited for satellite relays."

Based upon considerable written data and an extended discussion by a panel of technical experts, ARS proposes a definition for the "Earth/Space/Earth Service" as follows: "*Earth/Space/Earth Service:* A service of radio communication between positions on earth utilizing objects in space." The corresponding "Earth/Space/Earth Station" would be defined as "a station in the Earth/Space/Earth Service."

Frequency Allocations

In its comments, the Society praises the Commission's proposal for frequency allocations as a laudable start toward solution of a major international problem. But in the light of known present needs for frequencies in space applications, and after some consideration is given to the foreseeable needs for other forms of radio transmission in space projects, the technical experts consulted are unanimous in their view that FCC's proposals for frequency allocations to the "space radio" services are most seriously inadequate. Thus, W. H. Pickering states emphatically that "the frequency allocation proposed is not adequate for the presently planned space program." Richard W. Porter and Wernher von Braun also have commented on the lack of proposed frequency allocations in many parts of the spectrum.

In fact, several persons consulted in connection with the Society's comments professed surprise and concern that frequency bands which are now actively used in the space program have been omitted from the proposed table of frequency allocations.

The 1–2 mc Area.—Carl Seddon states that the 1.3–1.5 mc frequency band should be allocated to the Space Service. Frequencies in this band would not be used in the Earth/Space service. Seddon points to a need for this particular band only in regions beyond the atmosphere, specifically, 800 miles or more above the earth's surface. Dempsey also supports the use of a frequency in this range for the Space Service, urging that it be located in a part of the spectrum in which "the ionospheric shielding will protect the earth services from interference."

The 25.6–25.65 mc Area.—The experts agreed generally that the FCC proposal for a 50 kc band between 25.6 and 25.65 mc for the Earth/Space Service is satisfactory for elementary use of radio in space. However, several felt that in the long run this narrow bandwidth will be inadequate for all uses planned for this frequency range.

The 30–42 mc Area.—Because of the apparent inadequacy of the 25.6–25.65 mc band, and based on proposals of Dana Bailey, Alan Shapley, Warren W. Berning, and Russell Pope, the Society urges that frequencies in the 30-42 mc area of the spectrum be allocated to the Earth/Space Service. Drs. Bailey and Shapley, for example, propose that at least two frequencies about 1 mc apart be allocated for use in experiments on the effect of the ionosphere on radio propagation. They make specific reference to Questions No. 168(V) and 169(VI) adopted as a result of recent meetings of the International Radio Consultative Committee, calling for studies of ionospheric propagation phenomena, as well as a determination as to what are the optimum frequency bands for intercommunication between any two points in space, with particular reference to the earth and to rockets, satellites, and space vehicles launched therefrom.

ARS proposes that frequencies in the neighborhood of 37 and 38 mc be allocated (for the purposes described above) to the Earth/Space Service.

The 100–150 mc Area.—FCC recognizes the necessity of allocating frequencies in the 100–150 mc band, but no specific allocations were proposed. The Commission stated in the 16th Notice that consideration is being given to meeting the "stated requirement [of space radio] for frequency accommodations between 100 and 150 mc . . . in frequency bands presently allocated exclusively to Government

(CONTINUED ON PAGE 111)

For the record

The month's news in review

Feb. 2—Presidential report to Congress outlines NASA's 10-year space exploration program, divided into five general research areas—atmospheres, ionospheres, energetic particles, fields in space, and astronomy—and calling for launching of at least one satellite or deep space probe a month, starting in mid-1959, and firing of about 100 sounding rockets annually.

—NASA Chief T. Keith Glennan tells House committee urgent need now is for sustained effort in space exploration.

Feb. 3—AF Titan fizzles on launching pad in second launching attempt.

—AF coins new word, "Aerospace," to cover both earth's atmosphere and outer space.

Feb. 4—Rear Adm. John T. Hayward, Navy Research Chief, tells House probers space research must be under a single agency.

—AF Atlas takes off without a hitch.

Feb. 5—Democratic members of Joint Congressional Committee on Atomic Energy urge administration to authorize construction of nuclear-powered plane.

Feb. 6—AF successfully fires first Titan.

—Army Signal Corps announces that Snooper, 1000-lb reconnaissance drone built by Republic, has completed its first test flights.

—Defense Secy. Neil H. McElroy says decision against matching Soviet ICBM production missile for missile will be reviewed monthly.

—AF reports that first radar views of earth taken at 19-mile altitude from gondola of unmanned balloon have been returned safely to earth.

Feb. 9—AF School of Aviation Medicine marks 10th anniversary.

Feb. 11—Army weather balloon sets world altitude mark of 146,000 ft.

Feb. 13—AF contract for worldwide communications system able to work with weapons systems as far ahead as 1970 goes to ITT and RCA.

Feb. 16—AF test fires new R&D solid-fuel rocket about 40 ft long and much slimmer than Polaris at the Atlantic Missile Range.

Feb. 17—Navy sends Vanguard II—20-in., $21^1/_2$-lb weather observation satellite—into orbit around the earth.

—AEC Chief John A. McCone says development of a nuclear plane would require at least three years.

Feb. 18—Vanguard II begins to send data on cloud cover over earth.

Feb. 19—NASA reports more than $214 million in contract awards since agency was set up last Oct. 1.

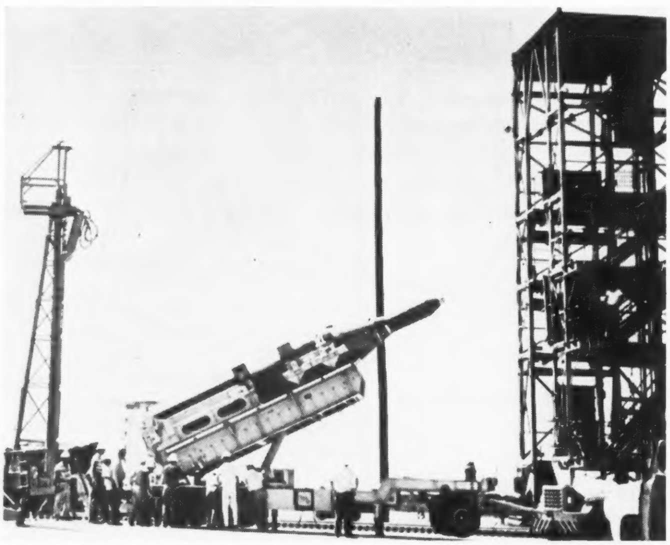
Feb. 20—AF Atlas blows up soon after firing.

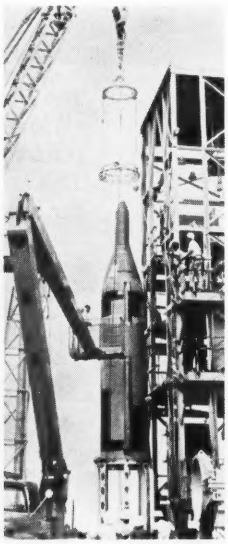
Feb. 24—Navy announces breakthrough in development of new steering nozzle made of molybdenum for Polaris and other solid-fuel missiles.

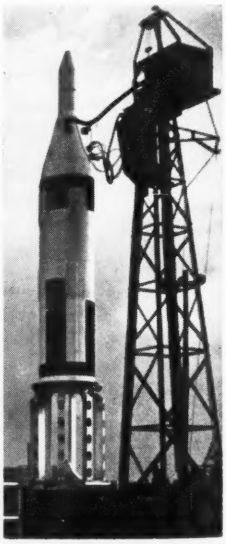
Feb. 25—AF Titan goes 300 miles in test flight.

Feb. 28—AF launches Discoverer I satellite from Vandenberg AFB. Orbit in doubt.

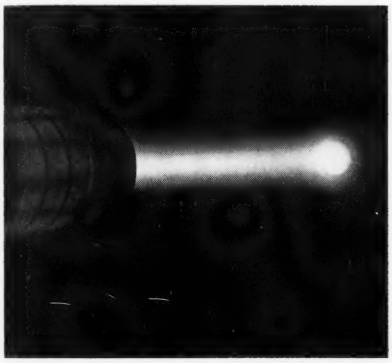
Polaris Takes Shape







A Polaris AX-1 flight-test rises in preparation for launching. Lockheed reports this Navy sub-launched IRBM well along in development.



COVER: *Sea-level run on a Marquardt RJ59 supersonic ramjet engine. The photo was taken during a run at the company's Van Nuys, Calif., test facility.*

Astronautics

APRIL 1959

Congratulations to Dr. Hagen

In Louvain, Belgium, last September, I replied to the polite query of a European about the relative weights of orbiting satellites launched by the Russians, compared to the tiny Vanguard I, by saying that those who can't make wrist watches must send up grandfather clocks. This boast was vindicated beyond dispute by Vanguard II, launched into orbit with a precision to match its exquisite perfection as a scientific instrument.

Dr. John P. Hagen deserves his country's highest praise for having the scientific integrity to hold to the highest standards of perfection in developing the most compact instrumentation package yet sent into orbit, and patiently progressing through failures to a perfect experiment on February 17. The data collected by this high-precision research device should do much to advance both the science of meteorology and space technology, enabling further refinements and a progressive series of successful Vanguards to follow.

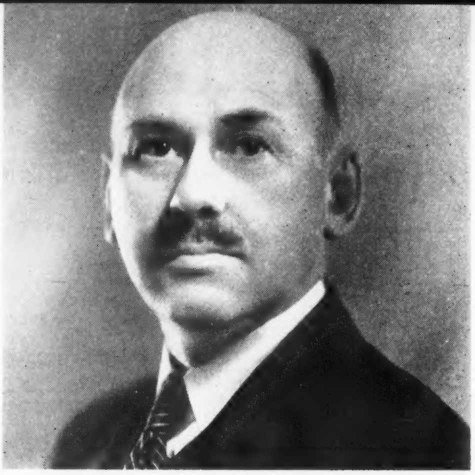
The American Rocket Society congratulates Dr. Hagen not only for his achievement but for his steadfast courage during a sustained ordeal of working under the most trying conditions.

John P. Stapp
President, American Rocket Society

Three Astronautical Pioneers — I

Robert H. Goddard

an autobiography



"It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow."

—ROBERT H. GODDARD

Background

Today's major achievements in the fields of rocketry and space flight stem to a large extent from the writings and teaching of three astronautical pioneers—Robert H. Goddard (1882–1945), an American; Hermann Oberth (1894–), a German; and Konstantin E. Tsiolkovskii (1857–1935), a Russian.

Some time ago, ASTRONAUTICS was fortunate enough to obtain a brief but fascinating autobiography of Tsiolkovskii which had not previously been published in English. The manuscript was accepted for publication, but it was felt that the picture would be incomplete without similar autobiographies of Dr. Goddard and Prof. Oberth, and efforts were immediately undertaken to see if these could be obtained.

Through the good offices of Esther C. Goddard, widow of Dr. Goddard and an ARS Honorary Member, a previously unpublished autobiography of the American rocket pioneer (written in 1927,) was obtained, and excerpts from this autobiography appear here. Taking Dr. Goddard from his early years to the time when the Smithsonian Institution published "A Method of Reaching Extreme Altitudes," they reveal in detail the motivating forces which got him interested in rocketry and space flight, and indicate for the first time the extent of his far-reaching early work. Mrs. Goddard has also been kind enough to supply the photos and facsimiles of Dr. Goddard's notebooks which appear on these pages.

The complete autobiography, as well as a vast amount of additional material from Dr. Goddard's own files, will be used as background in a definitive biography now being written by Milton Lehman, to be published by Farrar, Strauss and Cudahy next year.

Tsiolkovskii autobiography, as well as a new autobiography of Prof. Oberth especially prepared for ASTRONAUTICS, will appear within the next few months.

OWING to the widespread interest which is certain to arise later regarding space navigation, or interplanetary studies, it seems worthwhile to note the development of the writer's ideas and experiments upon the subject, together with a few personal facts which bear more or less upon this matter.

My earliest recollection of a scientific experiment dates back to when I was four or five years old, in Roxbury, Mass. I had heard of electric sparks being produced by a person who scuffed along a carpet, and I had seen electricity produced by a Leclanche battery, so one day I obtained the zinc from one of these batteries and scuffed along the gravel walk. Next, I mounted a low fence and jumped. Then I repeated the experiment, scuffing over a longer distance, and endeavored to convince myself I had jumped higher. My mother caught sight of this investigation and called out to me to be careful because it might work and I might go sailing away, without being able to come back. After this warning, I hid the zinc rod and never repeated the experiment.

An event of some interest occurred when I was taking impromptu examinations for the purpose of entering Roxbury Latin School. A number of my playmates planned on taking these examinations, and had been studying for them for some time, unknown to me. I remember that I entered into the spirit of the thing as far as I could, and earnestly endeavored to pass.

However, it was not with great surprise that I received a notice from the headmaster a few days later that I had not passed with entering grades. But I was surprised to learn, when I called on him, that, if it was any satisfaction to me, I had beaten them all in both mental and written arithmetic.

It was the first inkling I ever had that I was even of average ability in mathematics. Hitherto, arithmetic had merely been a subject in which I was continually making mistakes and achieving poor or unsatisfactory grades. I learned the principles easily enough and secured a variety of answers to the long problems in multiplication and division, although these answers seldom included the correct solution.

In the spring of 1898, perhaps because the sky appeared so attractive, I spent considerable time thinking how delightful it would be to have a small balloon attached to a thread which I could fly like a kite. An ordinary rubber or silk balloon, however, held no attraction. It had to be a permanent balloon, which would not require refilling. The obvious thing was therefore a balloon of thin aluminum filled with hydrogen.

Manufacture Proved Difficult

Attempts to manufacture thin sheet aluminum proved very unsatisfactory, but, after putting out the fire in the kitchen stove with my ladle of aluminum several times, I finally succeeded in obtaining some 1/100 sheet aluminum, which I formed into a pillow-like shape, sealing the edges with litharge and glycerine. Then followed the filling with hydrogen. A local drug store clerk caught my enthusiasm and spent most of one rainy morning helping me to fill the balloon. He also caught a very severe cold, but I was too excited to do that. Unfortunately, the balloon would not rise because the aluminum was too thick.

I imagine my innate interest in mechanical things was inherited from a number of ancestors who were machinists. At any rate, an event happened about this time which was destined to provide me with all the scientific speculative material I could desire. In January 1898, there appeared daily for several months in the *Boston Post* the story, "Fighters from Mars, or The War of the Worlds, In and Near Boston." This, as well as the story which followed it, "Edison's Conquest of Mars," by Garrett P. Serviss, gripped my imagination tremendously. Wells' wonderful true psychology made the thing very vivid, and possible ways and means of accomplishing the physical marvels set forth kept me busy thinking.

At that time, my Uncle George was living in the same house with us at Worcester, Mass. He could do wonderful little things about the house with wire and pieces of zinc, and his neat little workshop and

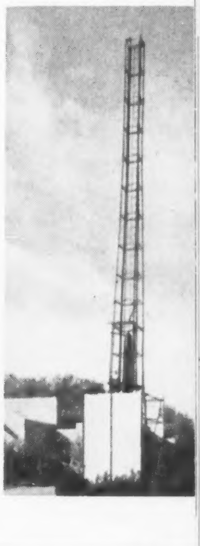
Roswell Museum to Open Goddard Wing This Month

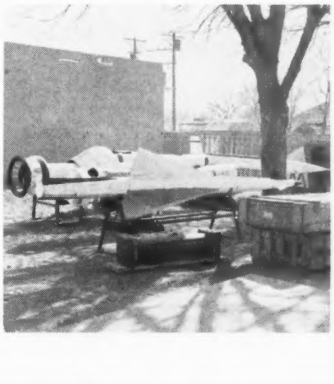
The Goddard Memorial Wing of the Roswell (N. M.) Museum will be opened to the public April 25 following special dedication ceremonies. Mrs. Robert H. Goddard, Army Under Secretary Hugh Milton, Sen. Clinton P. Anderson (D., N. M.), Harry Guggenheim and a host of leading figures in rocketry and astronautics are expected to attend.

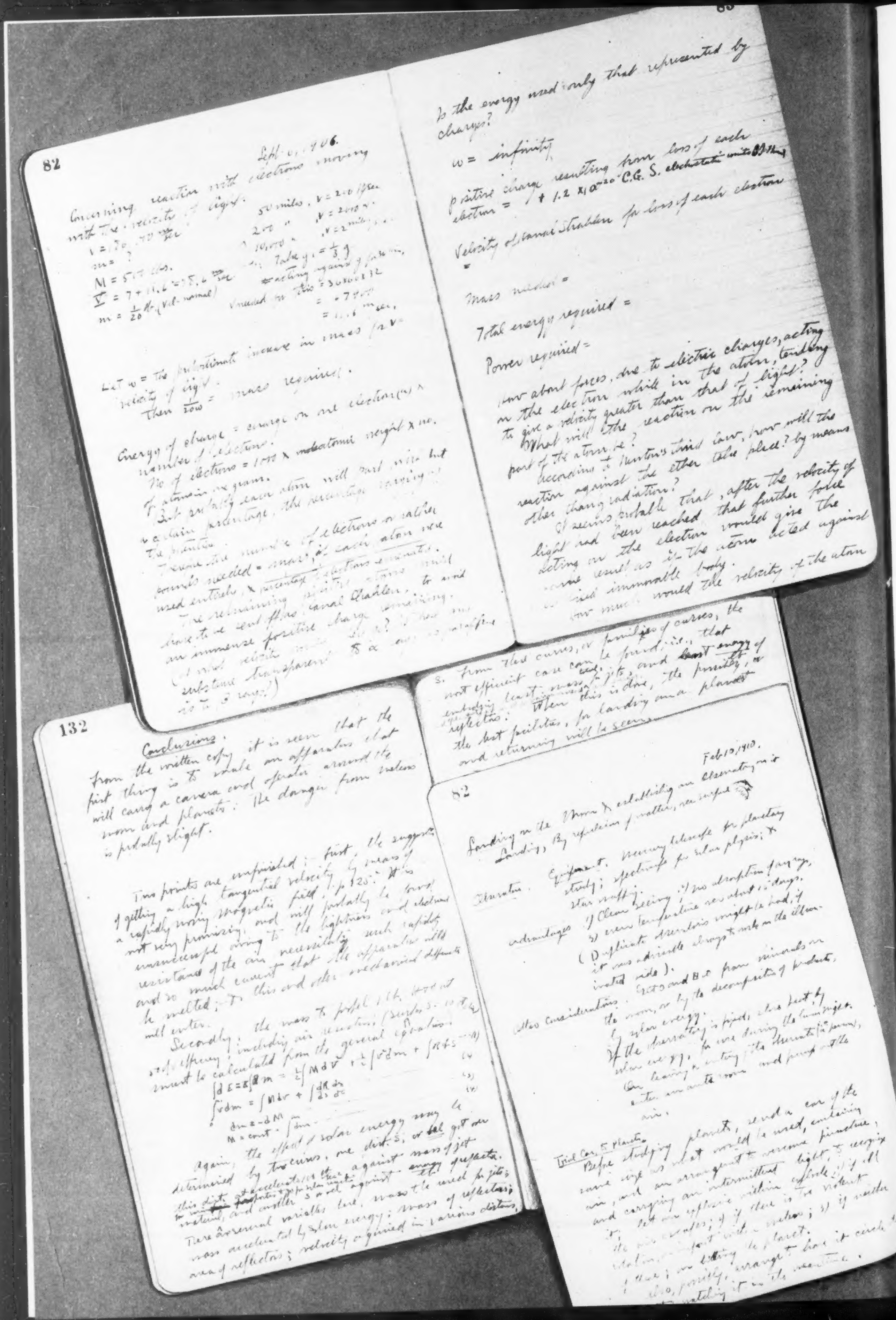
Both indoor and outdoor exhibits are planned and these are now being readied by the museum staff, headed by Director David Gebhard. The indoor exhibit will trace Dr. Goddard's experiments from around 1914 to his untimely death in 1945, concentrating on work done in the Roswell area. Materials exhibited will be supplemented by large photo-murals showing the Goddard rockets being built, tested, and fired. Other exhibits will trace the history of rocketry from his death to the present. The launching tower and observation tower used by Dr. Goddard in his Roswell experiments have been emplaced on the museum grounds, while a newly built courtyard will house the larger rockets and equipment.

A good part of the material to be exhibited was donated to the museum by Mrs. Goddard and the IAS. Funds for the necessary construction were made available through a grant from the Daniel and Florence Guggenheim Foundation.

Above, the Roswell Museum, with new Goddard wing at right. Highlights of outdoor exhibit are the launching tower (right) and some of the larger Goddard rockets (below)






82
Sept. 6, 1906.
Is the energy used only that represented by charges?
w = infinity
Mass needed =
Total energy required =
Power required =
132
Conclusions.
82
Feb 13, 1910.

tool cabinet in the shed was an unending feast to my eyes. This was the situation when, on the afternoon of Oct. 19, 1899, I climbed a tall cherry tree at the back of the barn and, armed with a saw and hatchet, started to trim the dead limbs from the tree. It was one of those quiet, colorful afternoons of sheer beauty which we have in October in New England, and, as I looked toward the fields to the east, I imagined how wonderful it would be to make some device which had even the *possibility* of ascending to Mars, and how it would look on a small scale if sent up from the meadow at my feet.

It seemed to me then that a weight, whirling around a horizontal shaft and moving more rapidly above than below, could furnish lift by virtue of the greater centrifugal force at the top of the path. In any event, I was a different boy when I descended the ladder. Life now had a purpose for me. Later in the year, I started making wooden models in which lead weights were to furnish lift by moving back and forth in vertical arcs, or strike against metal pieces as they whirled around horizontal axes. These naturally gave negative results, and I began to think there might be something after all to Newton's Laws, which I had read in Cassell's "Popular Educator," given to me by my father.

Newton's Third Law was accordingly tested, both with devices suspended by rubber bands and by devices on floats, and the said law verified conclusively.

This, however, did not put a stop to my interest, but made me realize that, if a way to navigate space were to be discovered, or invented, it would be the result of a knowledge of physics and mathematics. Not having had a course in physics, and having had a course in algebra in the English High School in which I had not particularly distinguished myself, I resolved forthwith to enter the new South High School in Worcester and shine in these subjects.

This proved easy in physics, at the hands of a very delightful and capable teacher. In mathematics, however, there was my previous distaste of the subject to overcome. I resolved nevertheless to lead the class in geometry and managed to do so despite the presence in the class of an exceedingly bright girl who was a natural mathematician. The plan which brought success was the making of a very painstaking book of original geometrical propositions. Any proposition I could think of I would try to prove, and then bring the result to my very patient and encouraging teacher. Some of the propositions occurred later in the course and some did not, but they made it a pleasure to think about geometry, which, perhaps, was the important thing.

Work at the attractive new school, with its complete equipment and enthusiastic teachers, was a pleasure. In December 1901, during my first year, I wrote a short article on the Navigation of Space and submitted it to *Popular Science Monthly*. The article mentioned how the idea of firing several cannons, arranged like a nest of beakers, had been proposed, and quoted figures on the frequency of meteors in space, which objects might make a collision likely. The article was not accepted.

During my two later years at the school, I spent a good deal of time considering the possibility of obtaining propulsion by a kind of machine gun device in which bullets were fired downward. I also experimented with gyroscopes under the erroneous impression that the tendency for the gyroscope to remain in one plane might be used to give a resultant force, just as a light card, in the air, can resist turning in such a way as to give a resultant force.

By the time I graduated from high school, I had a set of models which would not work and a number of suggestions which, from the physics I had learned, I now knew were erroneous. Accordingly, one day I gathered together all the notes I could find and burned them in the little wood stove in the dining room.

Dream Would Not Down

But the dream would not down, and inside of two months I once again caught myself making notes of further suggestions, for even though I reasoned with myself that the thing was impossible, there was something inside me which simply would not stop working.

At about this time, I bought a number of green cloth-covered notebooks with numbered pages, and started to make a systematic record of suggestions, setting down the date of each as it occurred. I had the advantage during this period of the excellent physics courses given by Worcester Polytechnic Institute.

The suggestions were very diversified, and concerned all sorts of possibilities. A summary of 26 methods, involving means in space, means taken with the apparatus, and means sent from the earth, was written Dec. 28, 1909. A brief outline of the most interesting suggestions will show that the fresh start made with these notebooks was worthwhile:

Large mass of explosive (CONTINUED ON PAGE 106)

Pages from Dr. Goddard's famous notebooks, dated from Sept. 6, 1906, to 1910, reveal references to ion propulsion, high energy propulsion systems utilizing solar energy collectors and lightweight propellants, and landing and establishing an observatory on the moon.

What we have learned from Vanguard

Our first earth satellite program unfolds as a drama of national *participation mystique,* with those on stage partially deceived by the audience

By Milton Rosen

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASHINGTON. D.C.

Milton Rosen, Chief of Rocket Vehicle Development for NASA, began his career in rocketry soon after receiving a B.S. in physics from the Univ. of Pennsylvania in 1937. From 1940 to 1945, he was a radio engineer on guided missiles for the Naval Research Lab. He was then a physicist in JPL's liquid rocket section until 1947, when he became head of NRL's rocket section, in charge of the Viking program. From 1953 until he took his present position last year, he was head of NRL's rocket development branch and then technical director of the Vanguard project. In 1954, he received the ARS James H. Wyld Memorial Award for his leading role in the highly successful Viking program.

Rosen gave his analysis of the Vanguard program at the 1958 ARS Annual Meeting, some three months before Vanguard II was launched into orbit Feb. 17 to become the world's first weather satellite. NASA predicts Vanguard II will stay in orbit a decade or more. This launching, notably unattended by the public tension and ballyhoo which enveloped earlier ones, adds significance to many of his observations.

WHEN people ask—"Has Project Vanguard been successful?"—the answer almost always is "No." I say almost always because there is a small but vehement group, consisting mainly of those involved in or closely associated with the project, who maintain that it has been successful if one views it in the correct light. They assert, for example, that "Vanguard has been at least as successful as other missile projects of comparable magnitude and complexity" or "Vanguard's success or failure must be judged in relation to the magnitude of the job, the time available, and the conditions under which the project had to operate." They point with justifiable pride to the fact that Vanguard placed one satellite in orbit (indeed, the most stable orbit attained to date) and also to the popularity enjoyed by Vanguard-developed stages in other space vehicles both proposed and in use. For instance, the Thor-Able lunar probe employs 16 rockets. Fourteen of these are Vanguard rockets, all except the vital first-stage Thor and the final retro-rocket.

Why, then, the question of success or failure? It is because political significance and wide publicity have taken Vanguard and like endeavors out of the realm of scientific investigation and placed them into the arena of public exploits. In this arena there is no payoff for near misses, good tries, or worthwhile experiments. Nor is anyone satisfied by the quotation of long odds. A horse that does not finish might just as well have been scratched.

Significant with Respect to Future Progress

But this can hardly be the viewpoint of an engineer. For him the important question would be, "What have we learned from Vanguard?" And it is the answer to this question that is significant with respect to our future progress in space flight and our standing vis-a-vis our competitor.

When one examines the Vanguard vehicle from an engineering aspect, it is difficult to see why its flight record has not been better. No one has seriously challenged the soundness of the basic design. The concept of a three-stage vehicle, consisting of two guided stages and a spin-stabilized final stage, has become a major prototype of first-generation space vehicles. A preset inertial guidance system, simple in concept, has proved to be well within the tolerance required to produce an orbit. Perhaps the most striking proof of the

Vanguard concept is the one existing long-lifetime orbit, which was achieved with a vehicle of less than nominal performance.

Turning from concept to design, one finds the Vanguard system design to have been consistently good. All three propulsion systems, when they have operated for full duration, have exceeded minimum required performance. One of these, the first stage, has exceeded its expected velocity increment in five successive flights. Every Vanguard rocket has been on course from its takeoff until the termination of its flight. Azimuth and elevation errors have rarely been more than one degree. No Vanguard flight has been marred by a structural failure despite the very low factors of safety and small margins that characterize the Vanguard design. Early fears concerning the integrity of various systems have proved unfounded. There have been no failures due to structural resonance, fuel sloshing, altitude starting, or stage separation. These areas are singled out because initially they were thought to involve very high risk.

Vanguard was developed against a limited time scale. Owing to the pressure of external events, the project elected to abandon its originally planned flight test program. Nevertheless, a vigorous firing schedule was being maintained. From January to June 1958, Vanguards were launched at the rate of one per month. And this pace could have been sustained. As late as July 1958, the Vanguard schedule called for the launching of all vehicles within the International Geophysical Year (IGY). At that time, however, the pressure to complete the program was relieved and the schedule of firings extended for an additional six months. I cite these facts to emphasize that, despite very severe setbacks, the project was capable of and intended to meet its announced plan of launching six satellites during the IGY.

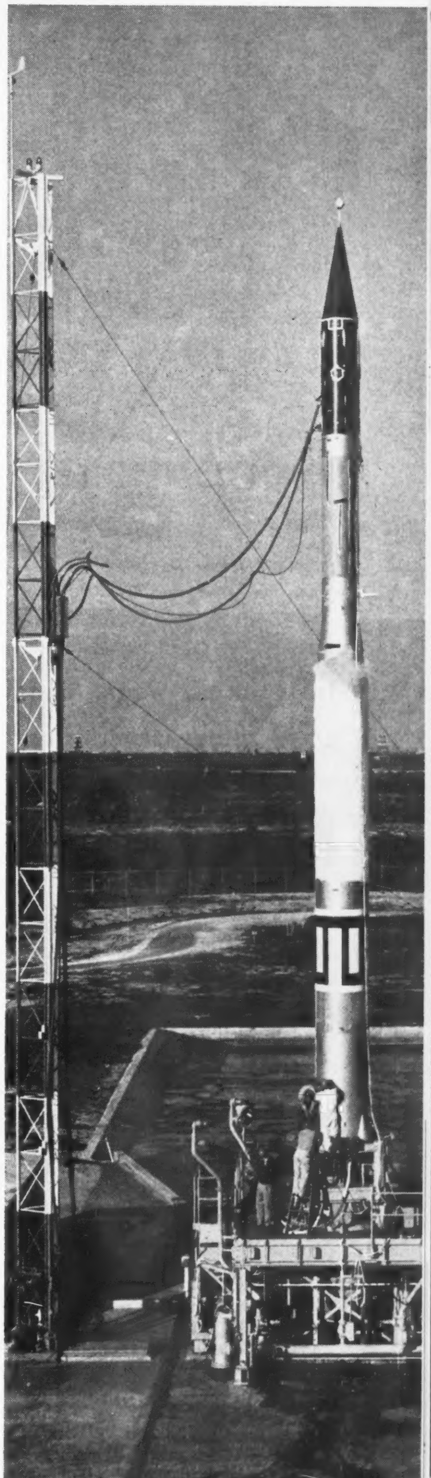
Look Behind the Scenes Is Necessary

Why then has Vanguard thus far failed to achieve its mission? The answer is not a simple one. It requires us to look behind the scenes—to examine more closely the fabric out of which Vanguard was made.

Although the post-Sputnik era is just one year old, it is already difficult for many people to think back to the summer of 1955 and to recall the general state of mind. The President's announcement that the U.S. would put up a satellite during the IGY was viewed by some with awe and by most with mild disbelief. The general attitude was perhaps—"Well, let's wait and see." But not the men who were charged with doing the job. They realized immediately the high stakes that were involved and the awful responsibility they had assumed. And it is not surprising that they should fix upon performance and schedule as their two major preoccupations.

Performance was defined very simply in terms of velocity. Anyone with a little knowledge of the mechanics of what we were doing knew that a number existed, that this number divided success from failure, and that the number was close to 25,000. It mattered little that the number was not known exactly, it was known well enough. And the number became more significant when one recalled that the highest velocity attained by a rocket to that date was 9000 fps. Hence, we were determined at all cost to fall on the right side of that vital number. What man would have done less?

The significance of the schedule was apparent. The dates of the start and the end of the IGY were fixed (CONTINUED ON PAGE 110)



Preflight Testing Vanguard

From *Krokodil,* March 10, 1954

Sign: Magazine Editorial Office
Comment: After the Editing . . .

Отредактировали...

Keeping up to date on Soviet astronautics

Analysis of the Russian periodical literature shows that, while there is as yet no single publication devoted to the subject, a good deal of space flight material can be found in certain magazines and newspapers

A physical scientist with Rand Corp., a nonprofit organization engaged in long-range research for the Air Force, F. J. Krieger is one of the nation's top authorities on Soviet missile and space flight capabilities. Author of "Behind the Sputniks: A Survey of Soviet Space Science" (Public Affairs Press, 1958) and editor of the famous two-volume "Casebook on Soviet Astronautics" published by Rand, Dr. Krieger has for a good many years been engaged in a careful check of the many periodicals mentioned in this article. He has been with Rand Corp. since it was founded in 1945, his main fields of research being the chemistry and physics of rocketry, as well as the science capabilities of the Soviet Union.

By F. J. Krieger

THE RAND CORP., SANTA MONICA, CALIF.

IN TRYING to select Russian periodicals he can read with profit and confidence, the Western reader interested in Soviet developments in astronautics is faced with a formidable, albeit challenging, problem. Because of the complex and devious manner in which the Soviets make information available to the world, the problem does not admit of easy solution.

Just as Western diplomats have found it difficult to "do business" on an equitable basis with the Soviet Union, so, too, are Western scientists finding it difficult to obtain cooperation from the Soviets in scientific matters. This attitude of recalcitrance and intransigence that characterizes Soviet dealings with the West is, of course, a manifestation of the dialectical principles of the philosophy of Communism. Crudely stated, this goes: "What's yours is mine, and what's mine is mine."

The discerning reader soon realizes that most articles in Russian newspapers, journals, books, etc., especially articles of the nontechnical variety, have been "censored," rather than "edited." The spirit of the process was admirably portrayed a few years ago in the cartoon at top of the page by I. Semenov in the Soviet humor magazine *Krokodil.*

In the Soviet press, there is no such thing as objective presentation of facts, scientific or otherwise. N. G. Pal'gunov, Director of *Tass,* the news monopoly that supplies most of the copy to the country's newspapers, wrote the following in 1956 in a brochure entitled "The

Bases of Information in the Newspaper: Tass and Its Role":

> News must be *organized,* else it is news of *mere events* and happenstance. . . . News must not merely throw light on this or that fact or event—*it must pursue a definite purpose.* . . . News is agitation via facts. In selecting the news topic, the writer of the news story must proceed above all from the realization that not all facts and not just any event should be reported in the press. . . . *News must be didactic and instructive.*

Examples of how this policy is committed to practice are numerous. Soviet successes in science and engineering are extolled in front-page lead articles, while Western achievements are barely mentioned on the last page. Significant information is glaringly omitted from *Tass* reports on the launching of Soviet scientific satellites and atmospheric research rockets and of the preliminary results obtained from the concomitant experiments. Historic events, such as the death of Pope Pius XII, are not even mentioned in the Soviet press. Misinformation is common. For example, the fate of Sputnik II's passenger, Laika, is still in question, since there is considerable disagreement between the official *Tass* statement and the unofficial statements of various Soviet scientists.

Although as far back as 1954 several Russian authors mentioned in their writings that a new journal entitled *Mezhplanetnye Soobshcheniya* (Interplanetary Communications) would begin publication in the Soviet Union, no such journal has as yet made its appearance. Even after three Sputniks and more than a year's membership in the International Astronautical Federation, whose official journal *Astronautica Acta* encourages contributions from scientists all over the world, the Soviets still prefer to publish their astronautical studies in their own rigidly controlled media. These media include newspapers, magazines (popular and technical), pamphlets, and books.

From the Western point of view, newspapers are not generally considered the most reliable and authoritative sources of scientific information. But in the Soviet Union there is one newspaper that has no peer and is above criticism. That newspaper is *Pravda* (The Truth), official organ of the Central Committee of the Communist Party of the Soviet Union. It is published every day of the year and has a circulation of about $5^1/_2$ million copies. Its primary function is, of course, to sound the Communist Party line in all matters, political as well as technological. In this regard, *Pravda* asserts its prerogative by being first to publish *Tass* announce-

Partial List of Soviet Newspapers Carrying Articles on or Pertaining to Astronautics

	Number of Issues Per Week	Annual Subscription Rate in Rubles
Pravda	7	72.00
Izvestiya	6	60.00
Krasnaya Zvezda	6	60.00
Sovetskaya Aviatsiya	6	60.00
Sovetskii Flot	6	60.00
Komsomol'skaya Pravda	6	60.00
Leningradskaya Pravda	6	60.00
Meditsinskii Rabotnik	2	42.00
Moskovskaya Pravda	6	60.00
Promyshlenno-Ekonomicheskaya Gazeta	3	46.80
Sovetskaya Rossiya	6	60.00
Trud	6	60.00
Vechernyaya Moskva	6	60.00

Note: Annual subscription rates in this and subsequent tables are taken from *Katalog Gazet i Zhurnalov na 1959 God* (Catalog of Newspapers and Journals for 1959), published by the U.S.S.R. Ministry of Communications. Subscriptions to most of these newspapers and periodicals may be obtained from the Four Continent Book Corp., 822 Broadway, New York 3, N. Y., at an exchange rate of 10 rubles per dollar.

Selected List of Journals Containing Articles on or Pertaining to Astronautics Published by Various Institutes and Ministries

	Number of Issues Per Year	Annual Subscription Rate in Rubles
Byulleten' Izobretenii	24	72.00
Kislorod	6	30.00
Meteorolgiya i Gidrologiya	12	42.00
Moskovskoe Vysshee Tekhnicheskoe Uchilishche imeni N. E. Baumana: Trudy	*	. . .
Nauka i Zhizn'	12	36.00
Priborostroenie	12	48.00
Radio	12	36.00
Radiotekhnika	12	60.00
Tekhnika-Molodezhi	12	24.00
Tsentral'naya Aerologicheskaya Observatoriya: Trudy	*	. . .
Tsentral'nyi Aerogidinamicheskii Institut: Trudy	*	. . .
Vestnik Akademii Meditinskii Nauk SSSR	12	72.00
Vestnik Leningradskogo Universiteta, Seriya Matematiki, Mekhaniki i Astronomii	4	40.00
Vestnik Moskovskogo Universiteta, Seriya Matematiki, Mekhaniki, Fiziki i Khimii	6	60.00
Vestnik Vozdushnogo Flota	12	. . .
Voenno-Meditsinskii Zhurnal	12	. . .
Voenno-Vozdushnaya Inzhenernaya Akademiya imeni N. E. Zhukovskogo: Trudy	*	. . .
Vsesoyuznoe Astronomo-Geodezicheskoe Obshchestvo: Byulleten'	2	. . .
Vsesoyuznoe Obshchestvo po Rasprosptraneniyu Politicheskikh i Nauchnykh Znanii. Seriya IV	36	21.60
Znanie-Sila	12	36.00

* Published irregularly.

Partial List of Journals Published by the U.S.S.R. Academy of Sciences That Carry Articles on or Pertaining to Astronautics

	Number of Issues Per Year	Annual Subscription Rate in Rubles
General Academic Journals		
Doklady Akademii Nauk SSR	36	518.40
Izvestiya Siberskogo Otdeleniya Akademii Nauk SSSR	12	84.00
Mezhdunarodnyi Geofizicheskii God: Informatsionnyi Byulleten'	*	Free
Priroda	12	84.00
Journals on Physico-Mathematical Sciences		
Astronomicheskii Zhurnal	6	99.00
Atomnaya Energiya (c 6 prilozheniyami)	12	144.00
Byulleten' Instituta Teoreticheskoi Astronomii	6	...
Fizika Metallov i Metallovedenie	6	150.00
Izvestiya Akademii Nauk SSSR: Seriya Geofizicheskaya	12	126.00
Pribory i Tekhnika Eksperimenta	6	90.00
Uspekhi Fizicheskikh Nauk	12	144.00
Zhurnal Experimental'noi i Teoreticheskoi Fiziki	12	288.00
Zhurnal Tekhnicheskoi Fiziki	12	126.00
Journals on Chemical Sciences		
Uspekhi Khimii	12	96.00
Zhurnal Fizicheskoi Khimii	12	270.00
Zhurnal Nauchnoi i Prikladnoi Fotografii i Kinematografii	6	72.00
Zhurnal Neorganichesko Khimii	12	270.00
Journals on Technical Sciences		
Avtomatika i Telemekhanika	12	135.00
Izvestiya Akademii Nauk SSSR, Otdelenie Tekhnicheskikh Nauk		
Seriya: Problemy Metalla i Topliva	6	75.00
Seriya: Problemy Mekhaniki i Mashinostroeniya	6	75.00
Seriya: Problemy Energetiki, Avtomatiki i Elektrosvyazi	6	75.00
Prikladnaya Matematika i Mekhanika	6	117.00
Radiotekhnika i Elektronika	12	165.00

* Published irregularly during the 1957–1958 IGY.

Selected Soviet Abstract and Reference Journals

	Number of Issues Per Year	Annual Subscription Rate in Rubles
Letopis' Gazetnykh Statei	56	120.00
Letopis' Zhurnal'nykh Statei	56	120.00
Referativnyi Zhurnal:		
Astronomiya i Geodeziya	12	115.20
Geofizika	12	115.20
Mashinostroenie	24	756.00
Metallurgiya	12	504.00
Mekhanika	12	172.80
Fizika	12	360.00
Khimiya	24	820.80
Elektrotekhnika	24	547.20

ments and reports on scientific and technological developments and to expatiate on these developments by means of editorials and articles by or interviews with leading Soviet scientists and engineers. Recently, Sputnik items which appeared in *Pravda* were collected and published separately as a 320-page volume entitled *Put' v Kosmos* (The Way into the Cosmos).

Among the many other newspapers in the Soviet Union that feature articles by and interviews with scientific and technical personnel on results achieved or studies under way in the field of astronautics are *Izvestiya* (News), the organ of the Presidium of the Supreme Soviet of the U.S.S.R., and the three military service newspapers published by the U.S.S.R. Ministry of Defense, *Kransnaya Zvezda* (Red Star), *Sovetskaya Aviatsiya* (Soviet Aviation), and *Sovetskii Flot* (Soviet Fleet). These newspapers are published six days a week. The circulation of *Izvestiya* is about one-fourth that of *Pravda;* that of the others is not known. The table on the previous page lists these and other prominent newspapers which are potential sources of astronautical information.

Newspaper Articles Indexed

Newspaper articles for the most part are indexed by author and subject in the bibliographic bulletin *Letopis' Gazetnykh Statei* (Chronicle of Newspaper Articles), published weekly by the All-Union Book Chamber, which is under the administration of the U.S.S.R. Ministry of Culture.

The various ministries of the Soviet Union publish several magazines of a popular science nature that feature articles by authorities on the advances and problems of astronautics. These articles, although nontechnical, are usually illustrated but not documented, and are somewhat more informative than are corresponding newspaper articles. The more readily available of these magazines, in order of ascending sophistication, are *Znanie-Sila* (Knowledge Is Strength); *Tekhnika-Molodezhi* (Technology for Youth); *Nauka i Zhizn'* (Science and Life); and *Priroda* (Nature), published by the U.S.S.R. Academy of Sciences. Also in this category are the amateur radio magazine *Radio*, the Red Air Force journal *Vestnik Vozdushnogo Flota* (Herald of the Air Fleet), and the monthly journal *Vestnik Akademii Nauk SSSR* (Herald of the U.S.S.R. Academy of Sciences.

Readers may recall that in the summer of 1957 *Radio* carried a series of articles instructing radio amateurs on how to prepare their gear for tracking the forthcoming Sputniks. *Radio* is an organ of the U.S.S.R. Ministry of Communication and DOSAAF (The All-Union Volunteer (CONTINUED ON PAGE 76)

One thing youngsters learned at the Bell Wheatfield plant was that rocket engines make a lot of noise.

Educating the amateur rocketeer

ARS Niagara Frontier Section's "Introduction to Rocketry" lecture and demonstration series fascinates youngsters, parents, and teachers alike while alerting them to the dangers of rocket experiments

DURING the past year, the ARS Niagara Frontier Section successfully ran a unique series of educational programs presented as a public service for amateur rocketeers, their parents, teachers, and others interested in the subject.

Under the title of "An Introduction to Rocketry," the series introduced basic rocket technology to a large number of young students in the Buffalo, N. Y., area who have become interested in the subject over the past few years. The purpose of the six meetings which made up the series was to promote a serious interest in rockets among youngsters in the area, and also to acquaint amateurs with the tremendous forces with which they were working in the hope that this would help channel dangerous experiments into nonhazardous but interesting and rewarding directions.

The programs were conceived by the Section's Education Committee, headed by Ralph Bloom of Becco Chemical Div., Food Machinery and Chemical Corp. Members of the committe are R. D. Roach Jr. and William W. Swenson, Bell Aircraft; Leo Goldschlag and Andrew J. Kubica, Food Machinery and Chemical (CONTINUED ON PAGE 96)

Irving Osofsky of Cornell Areonautical Lab clears up a point for two students.

Part II

Hypersonic aerodynamics

Workable theory requires defining flight regime in terms of vehicle shape and developing suitable simplifications to handle fundamentally nonlinear dynamics

By Wallace D. Hayes

PRINCETON UNIVERSITY, PRINCETON, N.J.

LAST month, we discussed effects of lift-drag ratio and velocity on the performance of hypersonic vehicles. We turn now to the aerodynamic theory associated with hypersonic flow about a vehicle.

Hypersonic aerodynamic theory is based on a number of conceptual simplifications which hold strictly only if the Mach number is made to approach infinity in a mathematical limiting process. In practice, of course, we might apply hypersonic aerodynamics at finite values of the free-stream Mach number (M_∞), and some guide is needed as to how large M_∞ needs to be in order that we may use hypersonic concepts. Any specification of values of M_∞ dividing ranges of application cannot help being arbitrary, and this fact must be kept in mind.

Any division of the Mach number scale into ranges is not only arbitrary, but must be made in context, with a particular set of hypersonic problems in mind. A division should be different for a blunt body than for a slender body, and should be different for the hypersonic flow of helium than for the hypersonic flow of carbon dioxide.

Suggested Division

We suggest this division for slender winged bodies in flight in our atmosphere:

Moderate supersonic: $1.2 \leqq M_\infty \leqq 2.5$. In this range the basic theory is the linearized theory, and interference effects are all important.

High supersonic: $2.5 \leqq M_\infty \leqq 3.5$. In this range the linearized theory must be strongly modified to take into account nonlinear effects; interference effects are still important.

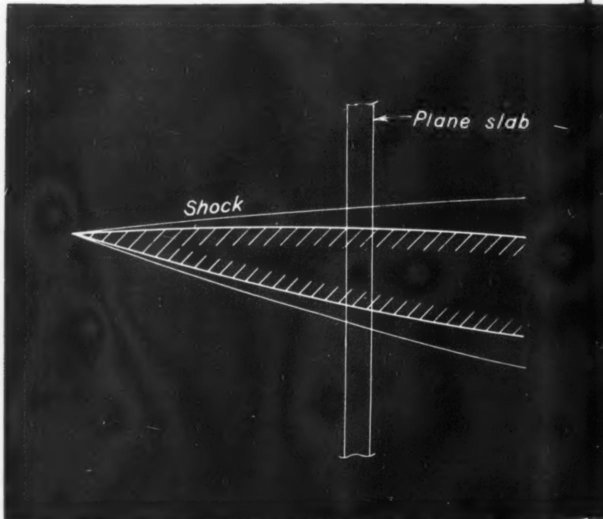
Low hypersonic: $3.5 \leqq M_\infty \leqq 8$. In this range aerodynamics are definitely nonlinear, and most of the characteristically hypersonic phenomena are evident; but the simplified hypersonic theories require correction, and the flow-fields cannot be considered to be fully hypersonic.

Fully hypersonic: $8 \leqq M_\infty$. In this range the simplifications based on the Mach number being large hold quite well, and interference effects are unimportant in most configurations.

Of these ranges, the middle two are the hardest to treat theoretically. Aerodynamic science for moderate supersonic speeds is well developed; highly successful airplanes have been built for this range. It is the last two ranges with which we are here concerned.

The preceding classification has been made with

THE EQUIVALENCE PRINCIPLE



hypersonic aerodynamic theory in mind. Choosing the velocity of sound in the lower stratosphere just above the tropopause as reference, any velocity may be converted into a Mach number. Arbitrarily choosing 200,000 ft as a representative maximum operational altitude, we note that potential energy at this altitude equals kinetic energy at about $M_\infty = 4$ and that at $M_\infty = 15$ or above the potential energy is much smaller than the kinetic energy. If a range of operating altitude of 50,000 ft is involved in a mission, the corresponding potential energy difference equals kinetic energy at about $M_\infty = 2$.

Satellite and related speeds may also be represented in terms of Mach number. The Busemann speed corresponds to about $M_\infty = 19$, satellite speed to about $M_\infty = 27$, and escape speed to about $M_\infty = 37$. These values are much higher than respresentative values of the Mach number following other possible classifications.

The most important characteristic of hypersonic aerodynamics is that it is fundamentally nonlinear. This nonlinearity affects not only the calculation of the principal aerodynamic force coefficients but also the control and stability of a hypersonic vehicle. Many of the concepts used in classical aerodynamics are based upon linearity, and must be discarded in treating hypersonic flow. For example, one classical concept we must drop is that of an aerodynamic center about which the moment coefficient is constant.

Moreover, conventional supersonic aerodynamic theory rests on a number of simplifying assumptions, e.g., equations of motion may be linearized and flow is irrotational. Most of these assumptions are also invalid for hypersonic flow.

Compensating for this loss of simplification, however, are a new set of simplifying assumptions available if the flight Mach number is very large. These assumptions and hypersonic flow theory are developed fully in a new book by Ronald F. Probstein (of Brown University and Avco Research Laboratory) and the author.

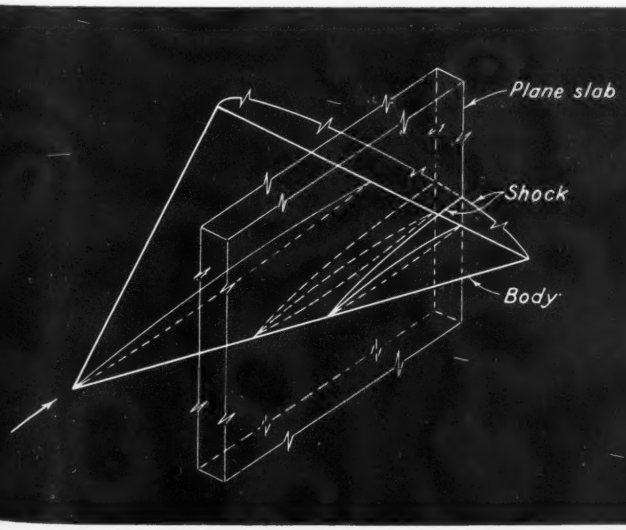
Primary Simplification

In brief, we can say that the Mach number independence principle is the primary simplification made in hypersonic flow theory. This principle, developed by Oswatitsch for an inviscid perfect gas as a similitude, states that at a certain value Mach number ceases to be an essential parameter in determining the flow-field; that is, flow becomes independent of the Mach number. As the Mach number approaches infinity in a limiting process, the flow pattern approaches or "freezes into" a limiting one. The principal requirement for validity is that the component of the free stream Mach number normal to the shock wave be everywhere large. Thus the Mach number independence principle comes into play at lower values of the Mach number for a blunt body than for a slender body.

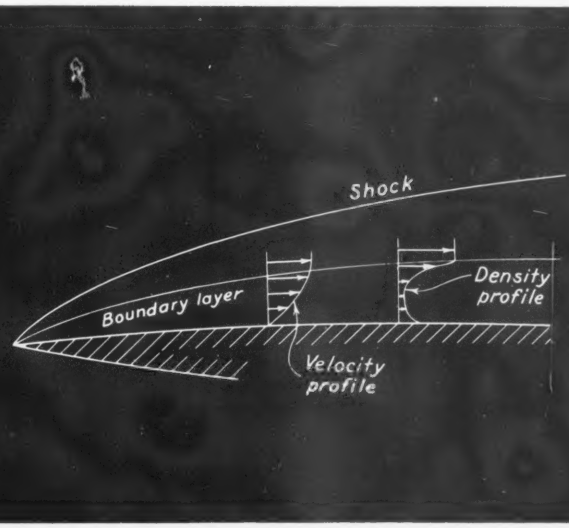
If the gas is not an inviscid perfect one, the approach of M_∞ to infinity must be carried out in a particular manner. The free-stream density (ρ_∞) and the free-stream velocity (V) must be kept fixed, and M_∞ increased by decreasing the free-stream speed of sound and, correspondingly, the free-stream temperature and pressure.

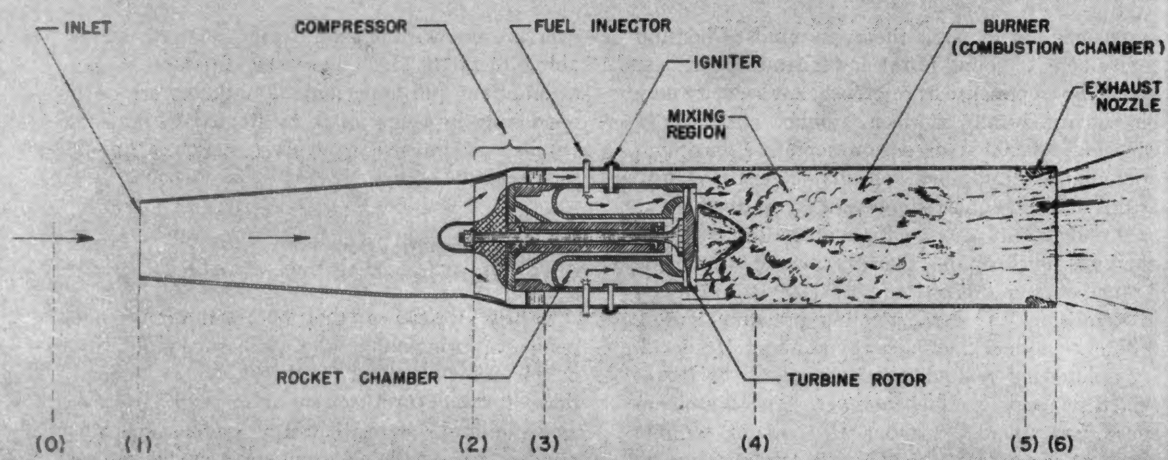
The physical idea behind the Mach number independence principle is, that at very high Mach numbers the free-stream pres- (CONTINUED ON PAGE 83)

STRIP THEORY



LAMINAR HYPERSONIC BOUNDARY LAYER





SCHEMATIC DIAGRAM OF MONOPROPELLANT AIR-TURBOROCKET ENGINE

Design for the future

A monopropellant air-turborocket

Use of such engines, with characteristics which offer a considerable choice to the designer, could mean smaller and lighter space vehicles

By James W. Mullen II

EXPERIMENT INCORPORATED, RICHMOND, VA.

James W. Mullen II has been president of Experiment Incorporated since 1945. He graduated summa cum laude from Princeton Univ. in 1939, and received a Ph.D. in organic chemistry there in 1942. Previous to heading Experiment Incorporated, he served as a research chemist with Monsanto Chemical Co. and Bell Labs and was a project supervisor at APL, Johns Hopkins Univ. He has done research in high-temperature fast-reaction-rate chemistry, jet propulsion and liquid propellant guns. Dr. Mullen is an ARS Fellow, and has been a member of its Ramjet Committee.

IN 1949, Experiment Incorporated, under the sponsorship of Navy BuOrd, initiated a program having as its objective the exploration of monopropellant propulsion systems based on a "double-reaction" or "mixed-cycle" principle. In the intervening years, this program led to the development of certain novel monopropellant rockets and gas generators and to a ramrocket powerplant flight-tested at supersonic speeds in May 1954.

The latest result of this program is the monopropellant air-turborocket engine (illustrated on the opposite page). In principle the air-turborocket cycle depends on the fact that certain monopropellants can be decomposed exothermically into reaction products which in turn are excellent fuels for an air-combustion process. The two reactions, decomposition and combustion, can be carried out in separate and distinct stages. Examples of such monopropellants are propyl nitrate, ethylene oxide, and acetylene.

Acetylene provides the simplest example of this principle, since it decomposes under the proper stimulus into its elements, carbon and hydrogen. There is simultaneous heat release, so that these decomposition products are available as an engine working fluid at a temperature of about 5000 F. The carbon and hydrogen can next, in a separate phase of an engine cycle, be burned with atmospheric oxygen to give the usual combustion end products, carbon dioxide and water. This second reaction makes available an even

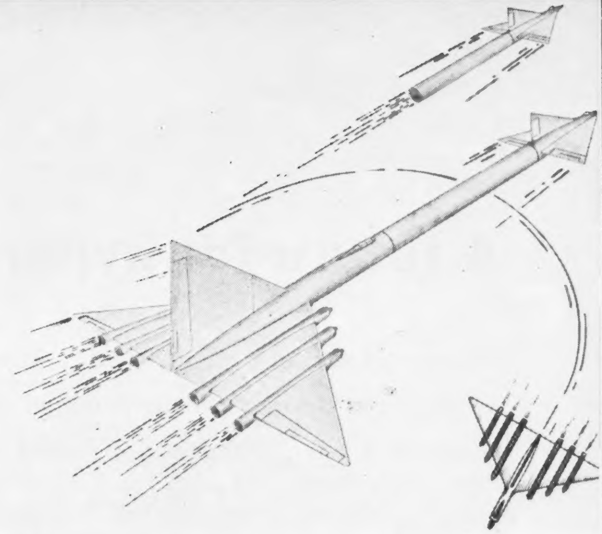
larger quantity of heat. This double-reaction principle is incorporated in the air-turborocket engine. The fuel is introduced into a chamber which for all practical purposes resembles a monopropellant rocket. In this chamber, decomposition (initiated, for example, by a flare) proceeds spontaneously to provide a high-temperature working fluid to a turbine rotor via a set of canted nozzles. The turbine extracts some work from this medium which is transferred by means of the centrally located shaft to drive a compressor. The compressor supplies high-pressure air to the entrance of the combustion chamber, at which point it becomes admixed with the still hot exhaust products from the turbine. These products being in themselves fuels, the second, or air-combustion, stage operates in a manner similar to ramjet or turbojet-afterburner operation.

Although at first glance the turbo-compressor unit may be reminiscent of a turbojet, it should be noted that none of the air, which is by far the larger weight fraction of the working fluid in this type of engine, passes through the turbine. Directly or indirectly, most of the performance features of the air-turborocket engine can be attributed to this fact. The mechanical complexity is much less than in a turbojet, and the efficiencies required of individual components, such as the turbine or compressor, are far less critical. While there is some evidence that the Germans during the latter part of WW II considered, at least from a theoretical viewpoint, an air-turborocket cycle, the rocket phase employed a conventional bipropellant fuel system, and the air-combustion stage was supplied by an ordinary hydrocarbon fuel from a second and separate fuel system. It remained for the program under discussion to pioneer the simpler, higher-performance monopropellant air-turborocket.

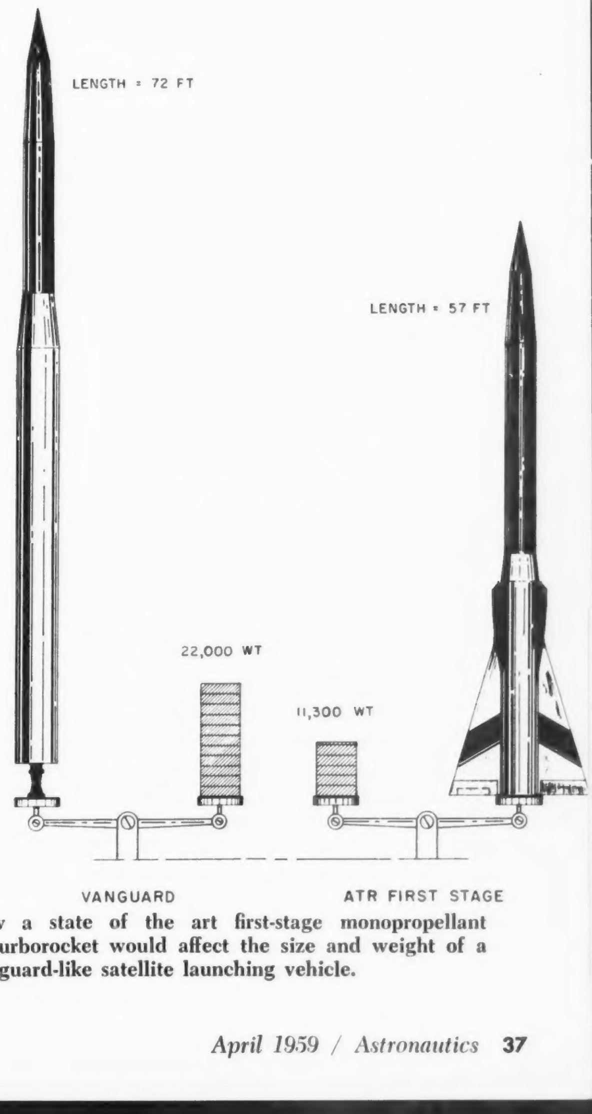
Offers Latitude to Designer

In its performance characteristics, the air turborocket offers a considerable choice to the designer. At one end of its operational range it possesses the high specific thrusts and low specific weights of a rocket engine. At the other end, it possesses the low specific fuel consumption of the ramjet or turbojet-afterburner combination. This does not imply that both ends of the performance spectrum can be most efficiently incorporated in a single engine design, nor does it imply that the specific thrusts associated with a rocket are achieved with the fuel economy of the usual air breathers.

For optimum performance, the engine should be tailored to the particular application at hand. For a mission whose most important aspect is superior rate of climb or high (CONTINUED ON PAGE 72)



A multimotored air-turborocket with guidance or a pilot to bring it back to earth safely could provide an economical means to launch missiles and satellite-bearing rockets from the edge of the lower atmosphere.



How a state of the art first-stage monopropellant air-turborocket would affect the size and weight of a Vanguard-like satellite launching vehicle.

A future for hypersonic ramjets

Missile, transport aircraft, and recoverable space vehicle booster applications appear practical within a decade, providing necessary research is done on hypersonic inlets, materials, and real-gas kinetics

By Gordon L. Dugger

APPLIED PHYSICS LABORATORY, JOHNS HOPKINS UNIV., SILVER SPRING, MD.

Gordon L. Dugger is project supervisor for hydrocarbon combustor development and research on advanced ramjet engines at APL. After receiving B.Ch.E. and M.S.E. degrees from the Univ. of Florida, he joined the Lewis laboratory of NACA (now NASA) in 1947. Most of his work there related to fundamental combustion research, and particularly to flame velocity and stability. Numerous papers and his thesis for Case Institute of Technology (Ph.D. in Ch.E., 1953) resulted from this research. In 1954, Dr. Dugger joined the staff of the International Minerals and Chemical Corp. in Florida, where he worked until coming to APL in 1957.

THE ADVANCES in rocket technology taking us into the space age led many people to belittle or even write off the future of supersonic air-breathing engines. However, now that several earth satellites have been put into orbit and new planets added to our solar system, there has been a renewal of interest in the potential of air-breathing engines. Oddly enough, the recent first-hand acquaintance of the public with high performance subsonic engines has probably done more in this revival of interest than the many scientific papers on supersonic flight which have appeared. We refer, of course, to the commercial introduction of the Boeing 707, DC-8, and Convair 880 turbojet aircraft, which have suddenly reduced cross-country flight times by 40 per cent.

Now that the airline operators have jet aircraft in service, they are looking forward to the next generation of terrestrial aircraft, and well they should. Few of us will ever travel through space for business or pleasure, but we shall all do more and more terrestrial traveling, and we'll want to do much of it at the fastest economical speed. Recent papers and panel discussions have shown that the aircraft industry and the airline operators expect to see Mach 2 to 3 airliners introduced in 8 to 15 years. The bolder forecasters suggest that this moderate supersonic speed era should be leap-frogged in favor of the introduction of Mach 3 to 5 aircraft in 1970, with the argument that such aircraft would then have an economical competitive life of 15 to 20 years. (For more detailed discussions of the factors bearing on the economy and timing of supersonic transports, the reader is referred to "Supersonic Transports [Proceedings]," Institute of Aeronautical Sciences 27th Annual Meeting, New York, N.Y., Jan 26–29, 1959.)

The writer would go even further and suggest that the optimum flight speed for intercontinental carriers will be nearer Mach 7, that much of the knowhow for building such aircraft already exists, and that if the planning were begun now it should be entirely possible to have Mach 7 transports by 1970. As for the other factors which will play an important role in the timing of such aircraft—such as the "supersonic boom" and traffic control—the solutions for the Mach 7 aircraft should not be appreciably different from those for a Mach 2 aircraft. Indeed, traffic control might be simpler in two regards—an aircraft embarking on a 3000-mile, 1-hr flight could be

cleared for landing before it took off, and the number of aircraft in the air at any time would be reduced because of greater aircraft utilization in terms of trips per day.

It goes without saying that if Mach 7 ramjets will be practical and economical for civilian transport by 1970, they will find use by the military even sooner. Another very probable use of ramjet engines developed for hypersonic transports would be in recoverable, maneuverable space-vehicle launchers. Such air-breathing launchers have been proposed and discussed many times, with good reason. Analyses have shown that the largest part of the operating cost of either hypersonic aircraft or recoverable launchers is the *fuel cost.* By any analysis that one can make, the air-breathing booster will have much lower fuel cost than a rocket booster.

There thus appears a promising future for hypersonic ramjet engines. What general forms might these engines take and how might they perform?

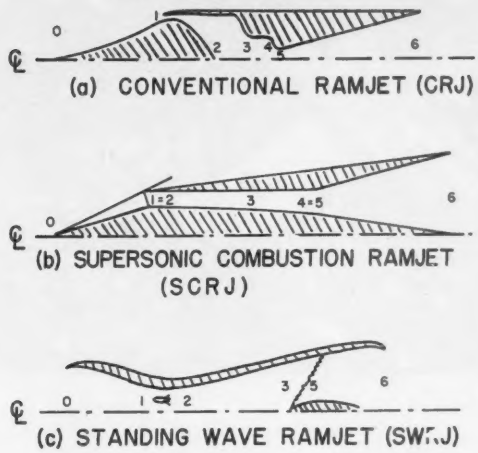
The conventional ramjet (CRJ) for hypersonic speeds might look something like the sketch shown in the first figure at top right. It has an isentropic external spike diffuser, followed by a relatively short subsonic duct, since the internal flow will be at very low Mach number. The combustion chamber would be small and short, because the time required for fuel-air mixing and burning will be very short at the high stagnation temperature, and because the heat transfer area should be kept small. The exhaust nozzle will have a high expansion ratio.

Conventional Ramjet Performance

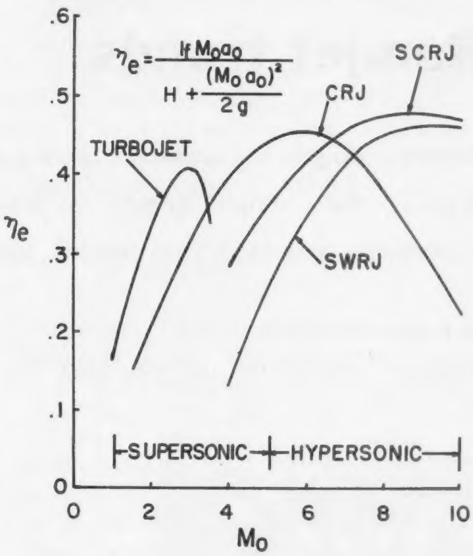
The performance of this CRJ is indicated in the second figure at right. It has been assumed that the diffuser kinetic energy efficiency is 0.90, the combustion efficiency is 0.95, and the exhaust nozzle velocity coefficient is 0.97. All exhaust nozzles are underexpanded, since it is assumed that the exit area should be only slightly larger than the air capture area. The CRJ curve represents on-design performance of a "rubber," or variable-geometry, engine. If, on the other hand, a fixed engine were designed for Mach 7 and required to fly over the range Mach 4 to 7.5, its efficiency would touch this curve only at Mach 7 and would be much poorer at all other speeds.

There is therefore a distinct need for variable-geometry inlets and nozzles for hypersonic vehicles, particularly if they are to be boosted only to Mach 3 or 4 by a turbojet or an air-breathing dual cycle engine, such as a turboramjet (a turbojet in parallel with a ramjet, with a common inlet and with air-flow division phased gradually from pure turbojet to pure ramjet as speed is increased). Other problems of this and the other (CONTINUED ON PAGE 114)

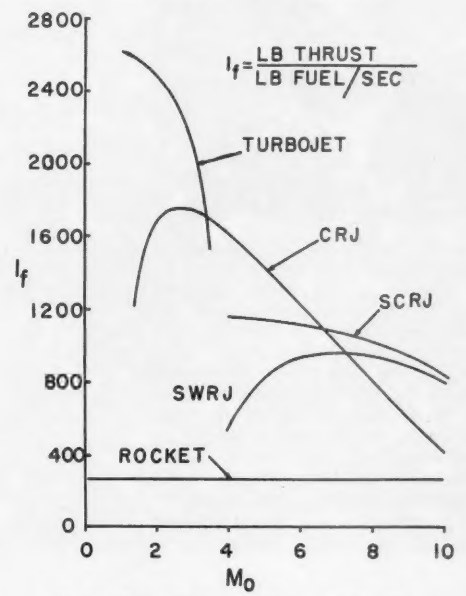
Hypersonic Ramjet Forms



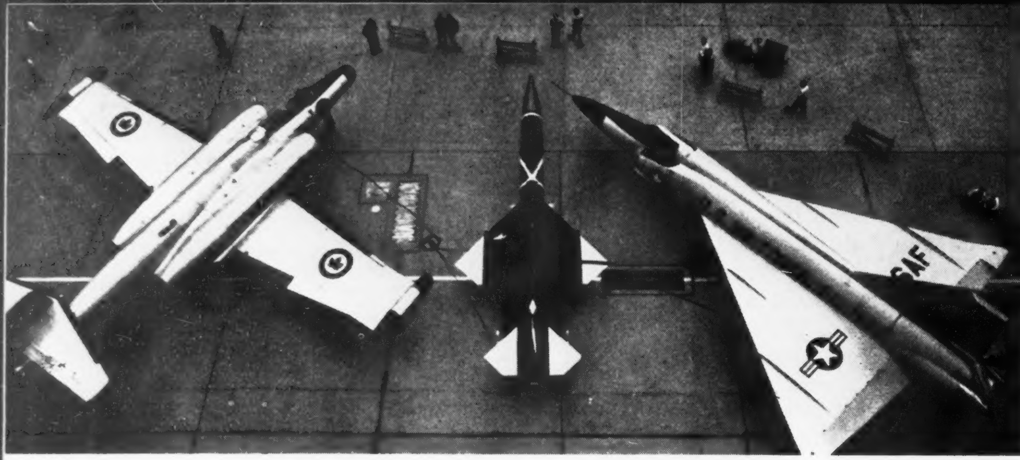
Efficiencies for Air-Breathing Engines



Fuel Economy Comparison



Air-breathers will be superior to rockets up to Mach 10.



Ramjet trends

Already highly successful in supersonic missiles and drones, the ramjet engine promises to advance to hypersonic speeds in commercial and military applications

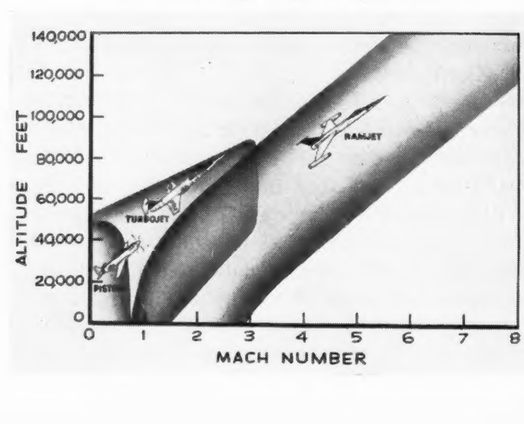
By Eugene Perchonok

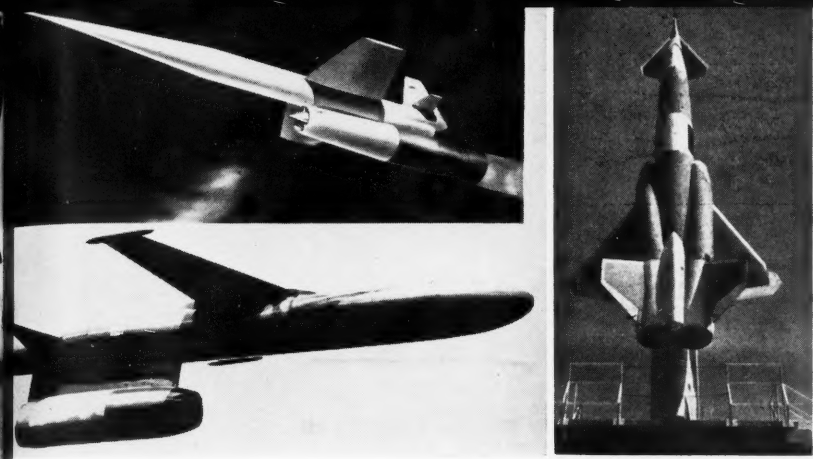
MARQUARDT AIRCRAFT CO., VAN NUYS, CALIF.

Eugene Perchonok is manager of hypersonic projects for the Astro Div. of Marquardt. An engineering graduate of the Univ. of Wisconsin, his ramjet experience dates back to 1945 and early NACA efforts in this area. He was with the Lewis Research Center for 14 years; and in addition to his pioneering work in all phases of ramjet engine development and evaluation, he was also concerned with early NACA experiments on the supersonic application of the turbojet engine. He is vice-chairman of the ARS Ramjets Committee.

THE RAMJET engine is a natural outgrowth of man's quest for speed within the earth's atmosphere. As does the wing or airfoil of the conventional airplane, the ramjet depends only upon its shape and the speed of flight to produce aerodynamic forces useful to man. An airfoil gives lift, the ramjet gives thrust. But both the airplane and the ramjet have the peculiarity of requiring forward motion to produce a useful aerodynamic force.

Air-Breathing Engine Spectrum





Ramjet applications: Left to right, Bomarc flanked by two current fighter aircraft; Talos on launcher; Kingfisher and Plover (bottom) drones; and Navaho.

In the November 1955 issue of Jet Propulsion (now ARS Journal), W. Avery succinctly documented ramjet history and early developments. He also described the operation of ramjets and indicated their performance and operating efficiency.

We turn here to an evaluation of trends in ramjet engine development and a survey of current ramjet applications.

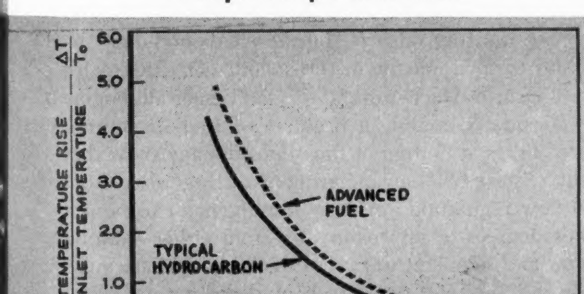
The areas of actual and potential ramjet application become immediately apparent after a brief study of the air-breathing engine spectrum. The illustration at the bottom of the opposite page represents the current situation for the popular air-breathing powerplants—the reciprocating engine with propeller, the afterburning turbojet, and the ramjet. Similar figures have often been presented; but continued advances and improvement in the jet engine art require periodic modifications and extensions to this spectrum.

The reciprocating engine with propeller combination is limited to subsonic speeds due to propeller inefficiency. This, of course, is also the case for the turboprop engine. The turbojet engine was the first of the air-breathing engines to find application in the supersonic range. Due to the high stagnation inlet-air temperature and the temperature limits at the turbine inlet, this engine is also speed-limited at approximately Mach 3.0.

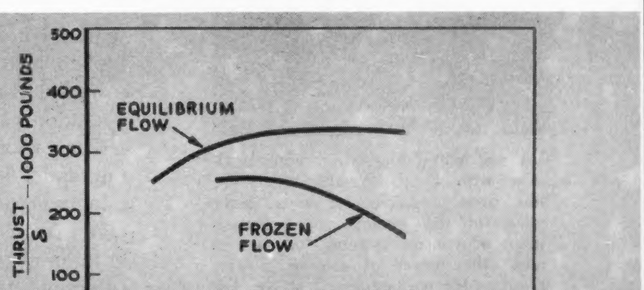
No Such Limits for Ramjet

The ramjet, on the other hand, encounters no such limit; and if the flight above Mach 3.0 is desired with an air-breathing engine, the ramjet, or some form of the ramjet engine, is the only currently known solution. Although ramjet impulse falls with Mach number in this speed range, its value remains above that for rockets to approximately Mach 12.0. One may conclude that if flight within the atmosphere is desired, the rocket, previously believed to be the only powerplant capable of hypervelocity flight, may find serious competition from the air-breathing (continued on page 100)

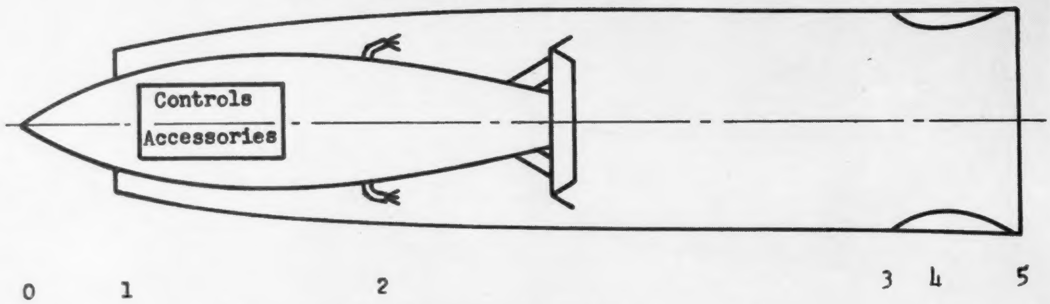
Ramjet Temperature Rise



Recombination Effect for JP-4



Fixed Geometry Ramjet Scheme



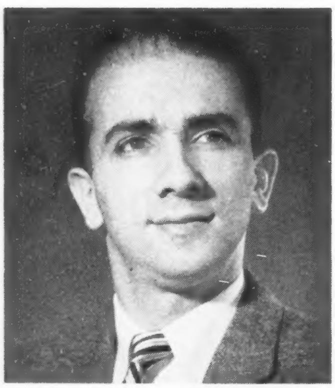
Stations: 0, free stream; 1, air inlet; 2, combustion chamber inlet or inlet-diffuser outlet; 3, combustion chamber outlet or nozzle inlet; 4, nozzle throat; 5, nozzle exit.

Ramjet fuel-air control

Efficient fuel-air metering underlies control of ramjet engine operation. . . Open and closed control loops for this metering both offer advantages

By Ludwig Muhlfelder

WRIGHT AERONAUTICAL DIV., CURTISS-WRIGHT CORP., WOODRIDGE, N.J.



Ludwig Muhlfelder is a project engineer with Curtiss-Wright, where he has been engaged for over eight years in the design and development of control systems for ramjets and other types of aircraft powerplants. He was educated at Newark College of Engineering, where he received B.S. and M.S. degrees in electrical engineering in 1950 and 1955, respectively.

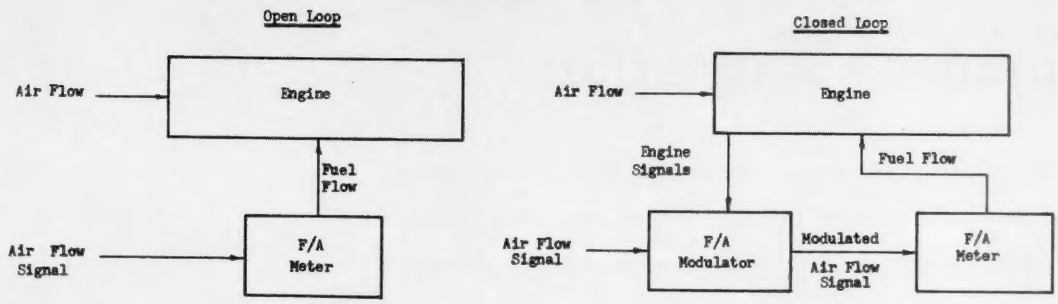
IN ITS simplest form, a ramjet consists of an inlet diffuser, a burner, an exhaust nozzle, and a power control. The sketch on this page shows the fixed geometry typical of a ramjet designed to operate over a relatively narrow Mach number range. A ramjet suitable for operation over a wide range of Mach numbers would require variable inlet and/or variable exhaust nozzle geometry. This article reviews briefly certain ramjet control fundamentals, and therefore will not discuss such special problems as variable geometry actuation, regenerative cooling, and fuel-manifold staging.

For a constant-geometry ramjet, controls and accessories have to perform the following basic functions: Initiate combustion; maintain the fuel-air mixture within required limits; pump the fuel to required heads; inject the fuel into the burner; and modulate the fuel-air mixture ratio to give maximum thrust and efficiency or to maintain control of cruise Mach number. Good over-all engine operation can be considered mainly a problem of fuel-air control.

The performance curves at bottom of the opposite page show that the ramjet basically requires fuel-air metering as distinguished from a faucet-type fuel flow regulation. Airflow intelligence can be obtained with various degrees of approximation from either external or internal pressures and temperatures. Over a limited Mach number range, for example, the total pressure behind the normal shock (impact pressure) can be utilized.

In general, better results can be achieved by sensing internal engine parameters to generate an airflow signal. This technique elimi-

Ramjet Fuel-Air Control



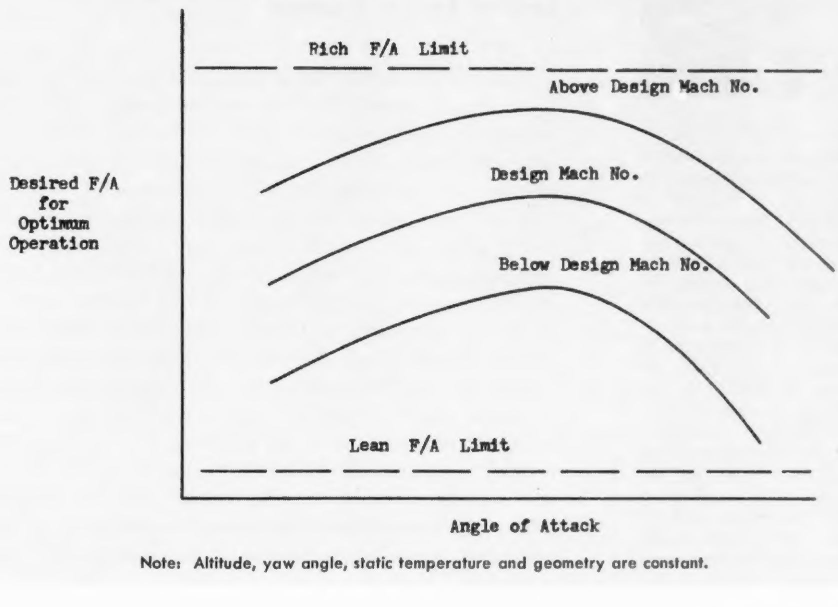
nates errors if either airflow or external engine signals deviate from their expected calibration with respect to various flight parameters.

The illustration above shows the two fundamental means of ramjet fuel metering. In the open loop system, fuel-air ratio can be scheduled as a function of such flight parameters as altitude, Mach number, angle of attack, and free-stream static temperature. A more sophisticated method consists of sensing internal engine parameters and modulating the fuel-air ratio to maintain optimum performance for all trajectory conditions.

A proposed system must be calibrated to allow for tolerances in the engine, control, and sensed signals. A tolerance probability study will disclose how much of a pressure-recovery margin is required to maintain the inlet at maximum efficiency compatible with stable operation, even at the most unfavorable off-design calibration point. De-rating the engine to allow for open loop tolerances results in a larger powerplant for a given thrust. Nevertheless, for certain applications this disadvantage in size is more than equalized by the relative simplicity of the open loop approach.

The closed loop system can receive airflow information from parameters which originate either externally or within the engine proper. The basic fuel-air schedule is modu- (CONTINUED ON PAGE 86)

Fuel-Air Requirements for Best Ramjet Performance



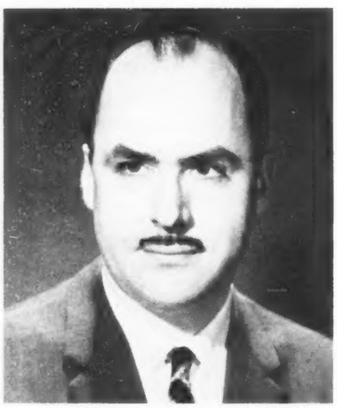
Note: Altitude, yaw angle, static temperature and geometry are constant.

Ramjet combustion

Theory has cut to size problems of low speed ramjets, but answers to combustion problems at hypersonic speeds await critical high-temperature experiments

By Roland Breitwieser

NASA LEWIS RESEARCH CENTER, CLEVELAND, OHIO



Roland Breitwieser is chief of the Propulsion Energy Branch at NASA's Lewis Research Center. He graduated from the Univ. of North Dakota in 1942 with a B.S. degree in mechanical engineering. Thereafter he worked briefly at the NACA Langley Memorial Lab, and then joined the Lewis Research Lab. The first high energy liquid-fueled ramjet combustors were developed and successfully flight tested under his direction. He also directed research leading to application of alkylborane fuels to ramjet and turbojet engines His more recent technical contributions are analytical papers dealing with the use of air-breathing propulsion systems up to orbital flight velocities. He is now engaged in research on extraction of electricity from ionized gases.

"A RAMJET combustor the size of a 50-gallon oil drum will produce more heat than all the home furnaces in a city of 25,000." "Air passes through a ramjet at several times hurricane velocity, yet flame is stabilized and proceeds efficiently." These statements are typical performance statistics frequently extolled by the enthusiastic combustion designer.

Stripping away some of the statistical bias, ramjet combustor performance appears quite commonplace. Space-heating rates in the local flame of a kitchen stove are several times that of the best ramjet combustor. The alleged hurricane velocities are present in ramjet combustors, but not in the initial reaction zones. The initial flames are carefully nurtured in a sheltered region away from the strong breezes, a practice well-recognized since cave man's mastery of fire.

What is unique about a ramjet combustor? What has kept the large task force of combustion scientists and engineers occupied these many years? What are some of the typical ramjet combustion problems?

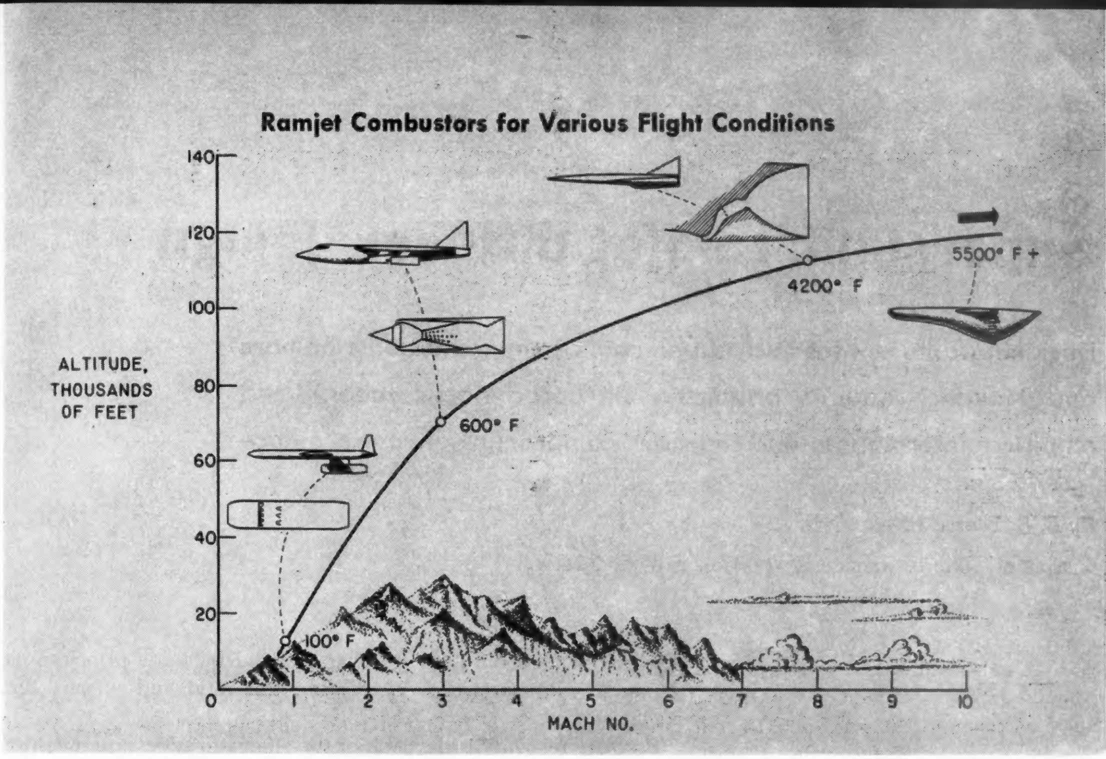
Lack of Typical Problems

Perhaps the most unique feature is the lack of typical problems. The "ramjet combustor" encompasses any combustion system in which ram compression is used as the start of a propulsive cycle. The size, shape, and mode of operation changes drastically as the combustors are applied to a range of speeds.

The illustration at the top of the opposite page summarizes various types of ramjets and their combustors. The subsonic ramjet experiences low inlet temperature and low ram pressure. Low ram pressure necessitates low pressure drop combustors.

Operating conditions become efficient as Mach 3 is approached. There higher stagnation temperatures are encountered, but the combustion air temperature is still moderate, permitting the use of standard materials and straightforward structural design. Combustor hardware allows precise control of fuel-air mixtures. This control coupled with favorable combustor pressure, temperature, and velocity results in excellent combustor performance.

The Mach 8 design is somewhat speculative. It illustrates how a combustor can be oriented to use the high pressure field under the



aircraft body, to minimize heat-transfer problems, and to provide adequate exhaust-nozzle area.

The configuration for Mach numbers greater than 10 is purely speculative. As flight speed increases, the problem of containing high temperature gases becomes more difficult. The sketch suggests that the combustion processes may be largely external in the high pressure field surrounding the body in order to alleviate some of the thermal problems. Conceivably, combustion could be all supersonic.

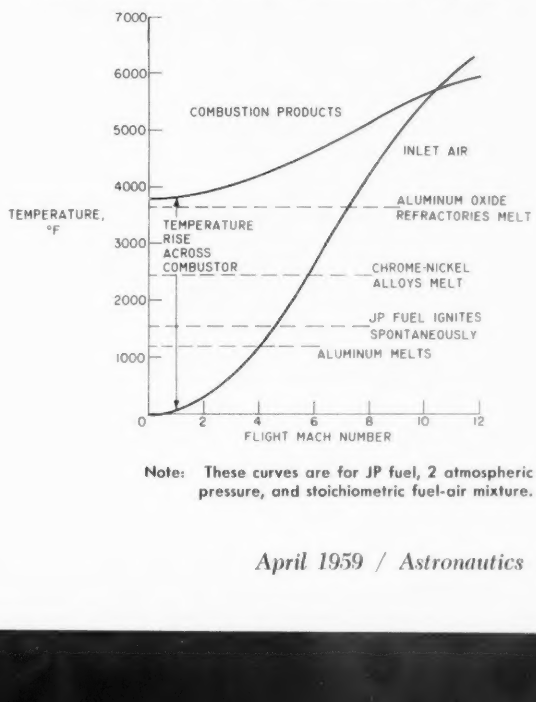
The operating variable that causes the large changes in combustor design is flight speed. Its influence is felt through stagnation temperature. The graph at right shows the variation in the combustor air temperature for various Mach numbers. It is evident that few conventional materials of construction will tolerate high flight speeds without some form of cooling. Included in this graph is the combustor-outlet temperature resulting from the combustion of a stoichiometric mixture of fuel and air.

At a low Mach number, the expected occurs; for example, at a Mach number of 1.0 the temperature rises from 100 to 3800 F during combustion. But as flight speed increases there is less temperature rise; the decrease in combustion temperature rise is due to dissociation of combustion products.

An interesting anomaly arises at Mach numbers above 10. Combustion of the fuel in the high temperature air causes the temperature to drop. The decrease in temperature is caused by the many energetic compounds that can be formed as fuel is burned in high temperature air. A useful ramjet propulsive cycle requires the conversion of this energy back into a translational form in the expansion process.

The rates of combustion (kinetic processes) are also influenced by flight speed. Fuels difficult to ignite at low Mach numbers suddenly inflame spontaneously as flight speed is increased only a few Mach numbers.

Thus far, we have em- (CONTINUED ON PAGE 87)



Note: These curves are for JP fuel, 2 atmospheric pressure, and stoichiometric fuel-air mixture.

Supersonic ramjet diffuser design

Designing diffusers for such supersonic ramjet vehicles as Bomarc and Navaho requires balancing of aerodynamic theory and empirical information, and judicious compromise on performance

By R. B. Pearce Jr.

MISSILE DIV., NORTH AMERICAN AVIATION, DOWNEY, CALIF.

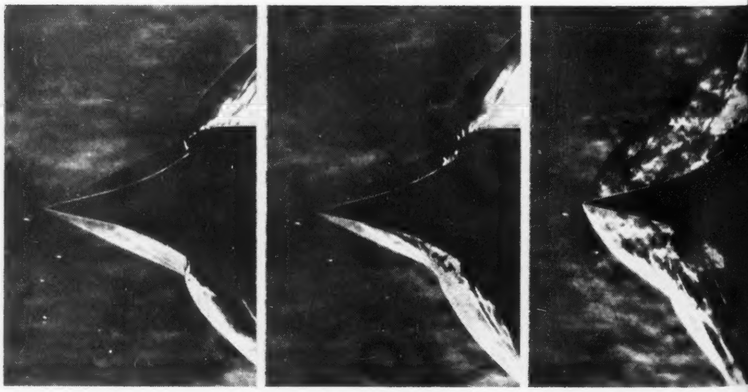
SUPERSONIC diffusers are characterized by three principal elements: Pressure recovery, capture area ratio, and external drag coefficient.

Pressure recovery is the ratio of the stagnation pressure measured at the burner entrance to the stagnation pressure in the free stream. As the free-stream Mach number increases, losses through the shock waves generated by the supersonic diffuser increase, so that supersonic inlets tend to decrease in pressure recovery capability at high Mach numbers.

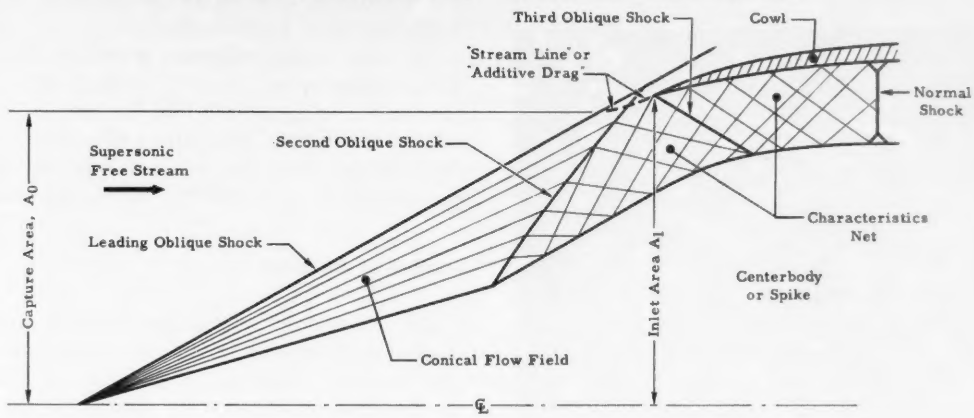
Capture area ratio is the area in free stream occupied by the internal flow prior to entry into the diffuser divided by the total cross-sectional area of the inlet. This is a measure of the airflow capability of the inlet. Since it is defined in terms of geometrical areas, it is not a function of flight altitude, such as is the more usual airflow measurement in pounds of air per second.

External drag includes the skin friction and pressure drag of the cowl, boundary layer bleed drag, and a computed drag termed "additive drag," or, as it is sometimes referred to, "streamline drag."

R. B. Pearce is chief of Aero-Thermodynamics for the NAA Missile Div. He received a B.S in mechanical engineering from Texas A&M in 1942, an M.S. in aeronautical engineering from CalTech in 1944, and an M.S. in applied physics from UCLA in 1950. Before joining the staff of North American in 1946 as an engineer on supersonic wind tunnel design and operation, he saw duty in the Air Force at Wright Field's engineering division. At North American, he has done a variety of research in aerodynamics, including studies of supersonic diffuser design.



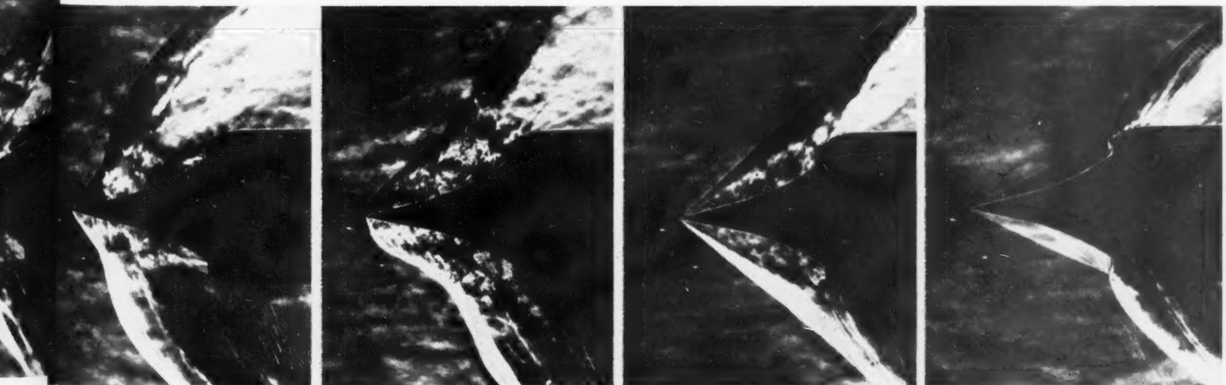
Flow-Field Construction by "Method of Characteristics"



The latter is a little more descriptive, since one way of computing the term is to integrate the pressure rise along the streamline which bounds the airflow captured by the inlet. This term is included in the drag because of the convention for computing the thrust of air-breathing engines. In this convention, thrust is defined as the momentum of the flow leaving the engine minus the momentum of the air in the free stream captured by the inlet. The change in momentum between the free stream and the inlet station of the air spilled around the inlet is the "additive drag." Since the thrust definition overstates the thrust, by this amount, the additive drag is applied to bring the net force on the airframe to the correct value.

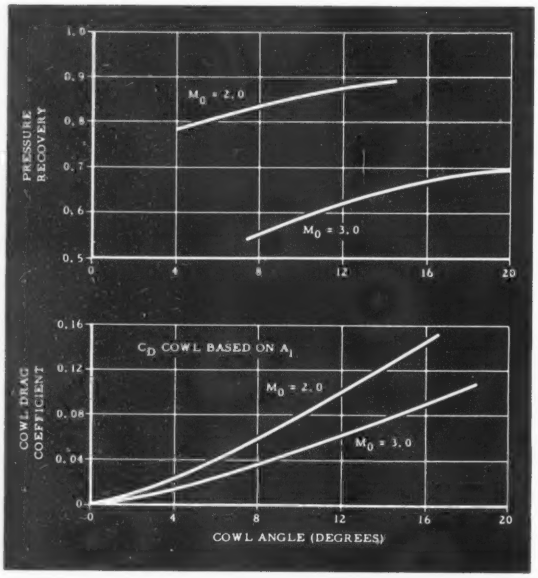
There are two major objectives in diffuser design. One is to convert the supersonic air stream to a high-pressure subsonic flow for the jet engine to use. The success of this objective is measured by the magnitude of the pressure recovery and the smoothness of the air stream entering the engine. The center-spike type of inlet compresses air to reasonably high pressure recovery by deflecting the air stream radially, thus slowing it and compressing it through oblique shock waves. This radially deflected stream must be collected by the cowl and then turned back toward the original direction for use in the engine. Both the radial deflection by the center spike and the inward deflection by the cowl create oblique shocks, and thus decelerate and compress the air stream with rather small losses in pressure recovery.

However, the final transition to subsonic flow must be made through a normal shock, and it usually is done with a rather large loss in pressure recovery. If the supersonic stream has been deceler-



One cycle of inlet buzz shows these progressive phases: Left to right, supercritical operation, with oblique cone shocks; flow separation traveling down the spike; separation complete to spike tip; reverse flow, with air spilling from inlet, reverse flow ended, separation decreasing; shock patterns approaching normal and separated flow entering inlet again; and again supercritical operation.

Inlet Design Optimization Study



ated to nearly sonic speed by oblique shocks, the large angle of the resulting flow requires a rather sharp turn to lead the flow to the engine. This abrupt turn generally causes flow separation and large losses in the throat of the inlet. If, on the other hand, the angles are kept small, then the flow entering the inlet is at such a high supersonic Mach number that the losses through the normal shock wave are large. A gradually turning cowl, which would probably have rather high pressure recovery, would also have high drag.

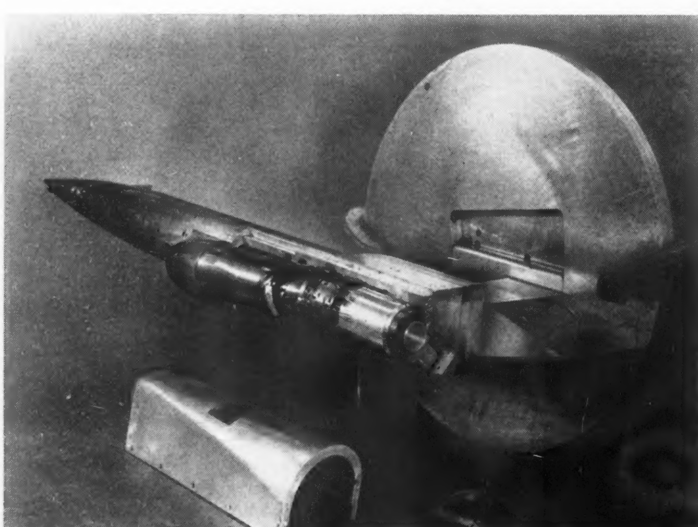
The other design objective is to keep drag low. This is done by keeping the external angle of the cowl to a low angle with the free stream and by making the capture area ratio nearly 1.0. Any air deflected by the spike but not captured by the cowl contributes "additive" or "streamline" drag.

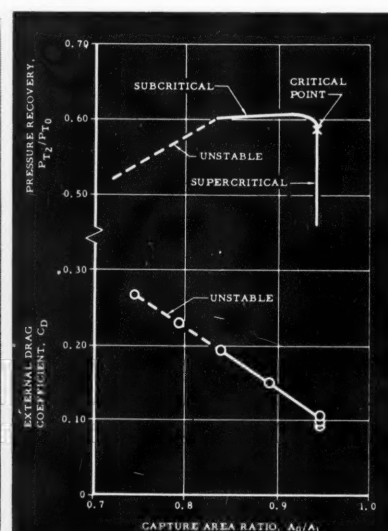
Design of an Inlet

The actual design of an inlet depends much on empirical information as well as aerodynamic flow-field analysis. Starting with the analysis, tables of the flow-field about cones are used to find the Mach number and flow direction behind the initial oblique shock from the tip of the cone. These cone flow properties are used with the "method of characteristics" to construct the flow-field, as indicated in the figure at the top of the preceding page. The construction calculates the effect of the turns in the surface of the cone and the deflection of the cowl.

This characteristic solution ignores the effects of viscosity, and thus of boundary layer growth and separation problems. The strong pressure gradients formed by the compression of the flow lead to boundary layer separation problems, particularly in the throat of the inlet. To reduce this separation problem aft of the throat of a fixed geometry inlet, the diverging subsonic diffuser is kept to a small angle, 1 to $1^1/_2$ deg for approximately $1^1/_2$ to 3 inlet diameters downstream (CONTINUED ON PAGE 68)

Navaho Drag Model and Associated Data





Missile market

BY JEROME M. PUSTILNIK, Financial Editor

GAZING spaceward for some time at the missile market's lofty levels may have prevented us from appreciating investment opportunities in an opposite direction—underwater. Long becalmed investor interest here may get underway as the press begins to highlight developments in this area.

While this interest starts with nuclear submarines and the Polaris and Subroc missile programs, it will broaden to include pure research projects, R&D programs in anti-submarine warfare, weapons systems, and hardware procurement. Future expenditures in the underwater field are expected to increase, percentage-wise, at a faster rate than in any other single area.

This activity has clear implications. The submarine armed with medium-range missiles is probably the most potent weapon system threatening our security today, since no part of the U.S. is more than 1500 miles from submarine waters. We are still unprepared for this threat, and much of the potential battleground is uncharted. (As an illustration, to date only 2 per cent of the ocean bottom has been mapped.) Not surprisingly, therefore, the NAS Committee on Oceanography recently recommended a 10-year, $651 million research program. In this budget, $100 million is earmarked for the development of more accurate, effective, and trouble-free instruments for deep-sea study and scientific exploration. In addition, the Navy has announced that it will spend $132 million for R&D work in the anti-submarine warfare (ASW) field, and that ASW is its No. 1 concern today.

The primary means of submarine detection are: 1. Sonar; 2. detection of a sub's magnetic field; and 3. infrared. All of these three ASW fields have promise. For the foreseeable future, however, the chief method of detecting fast-moving submarines will be sonar.

GE, Raytheon, Bendix, General Dynamics (through its Stromberg Carlson Div.), Edo Mfg., and Sangamo Electric are all active in the sonar field, with Sangamo one of the largest and most prominent. At its current price, we believe this latter company to be outstandingly attractive for the long-term investor who seeks participation in the ASW area.

Historically, Sangamo has been a major supplier of electrical equipment to the public utility industry. Its growing importance in electronics has, however, been generally overlooked, although military and industrial electronics sales now account for over 50 per cent of total volume. Almost all sonar detection equipment installed on U.S. naval vessels today is Sangamo engineered and built. A complex electronic system, sonar requires an ultrasonic generator and transmitting system, an audio and video display receiving system and associated range computer, azimuth computer, control indicators, servo mechanisms, and video circuits.

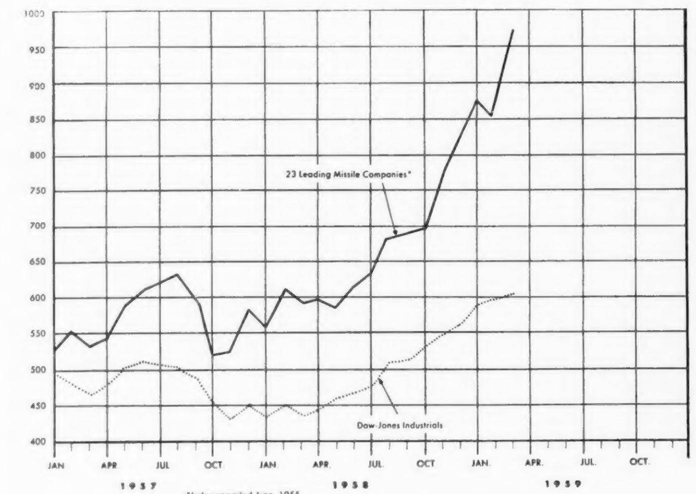
Design of sonar systems has developed production knowhow enabling Sangamo to produce other precision components such as filter networks, power supplies, and magnetic amplifiers for both commercial and military applications. Capacitors for electronic and electrical applications are also among Sangamo's electronic products, accounting for 20 per cent of total sales. New models have been developed for electronic computers, industrial machinery controls, and communications. Digital and magnetic tape recorders designed to meet the requirements of many data processing systems are manufactured by a subsidiary. Present volume in this area is small, but the potential is very large.

Sangamo's well-known watt-hour meters, which are benefiting from the successful introduction of new models, are part of a broad line of electrical energy measurement instrumentation that account for 45 per cent of company sales. Sangamo is the nation's third largest producer of this equipment.

Although sales and earnings slumped during the first nine months of 1958, reflecting the production gap in sonar and ASW equipment (sales were 26.5 per cent lower, while earnings were only $0.77 a share against $2.98 in 1957), military electronics business increased in the last quarter and net for the last three months spurted to an estimated $1.25 a share. For the full year, earnings of above $2.00 a share will compare with $3.49 the year before. In 1959, earnings

(CONTINUED ON PAGE 120)

THE MARKET AT A GLANCE



	March 1959	Feb. 1959	% Change	March 1958	% Change
Dow-Jones Industrials	603	594	+1.5	440	+37.0
Missile Index	972	856	+13.6	593	+63.9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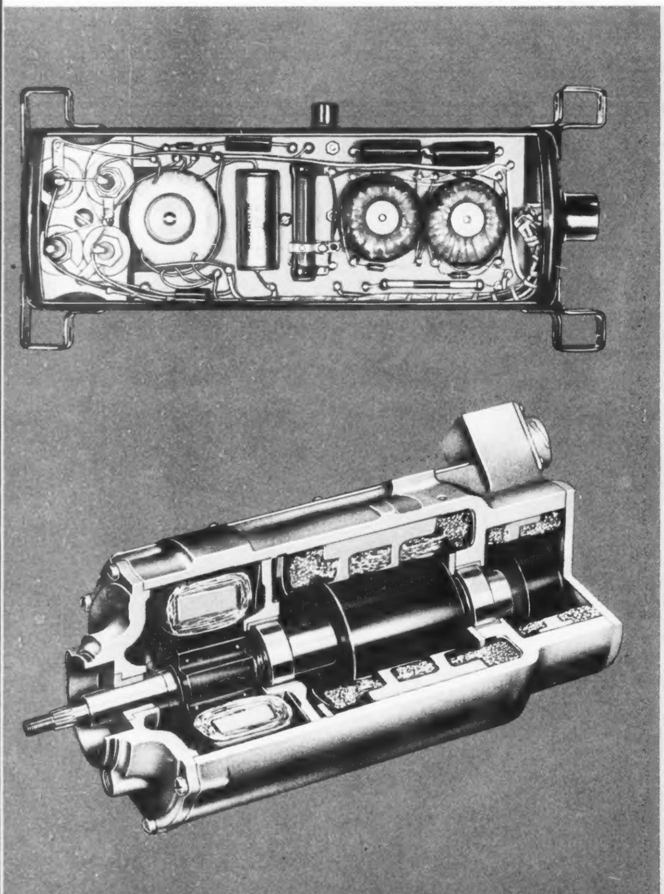
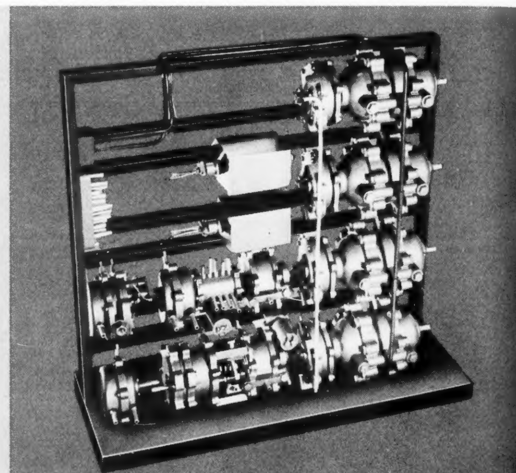
Your project may require microwave subsystems and components. Or a complete ground support check-out device. Or servo-controlled subsystems and components for a whole new vehicle concept. On each of these the TAPCO Group can design, develop, and manufacture your requirements on schedule.

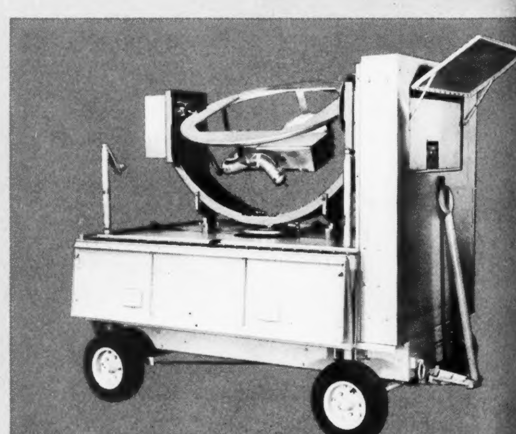
The TAPCO Group is experienced in the design and manufacture of electronic controls, including closed-loop servo systems and components, positioning controls, and small power-system alternators. Experience with microwave components includes coaxial and wave guide switches, power dividers, stripline microwave



APU tuned circuit speed control and alternator TAPCO designed and produced for 2400/400-cycle surface-to-air missile power. Alternator uses new-type permanent magnets that are fully short-circuit stable. Also incorporates unique flux-switching generator for speed control.



AICS, a high temperature (600°F) pneumatic computing control system, designed for air-induction inlet control or thrust reverser control for jet aircraft.



Precision position and speed servos in this TAPCO-developed ground support unit perform programmed check-out of missile guidance equipment. Readily adaptable to advanced antenna positioning and tracking systems.

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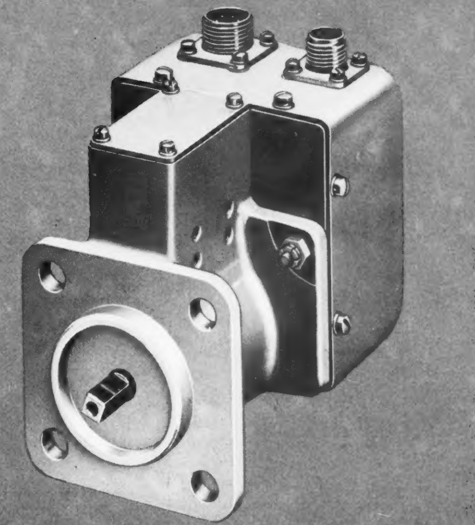
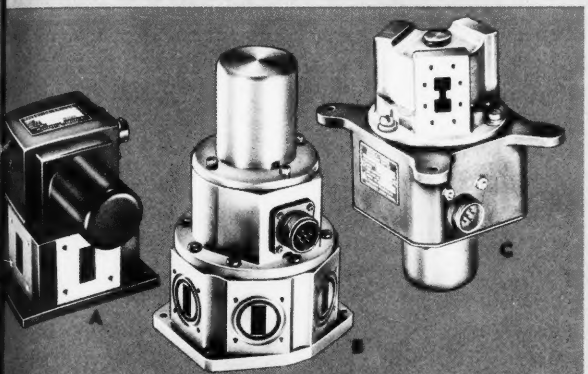
filters, and microwave antennas.

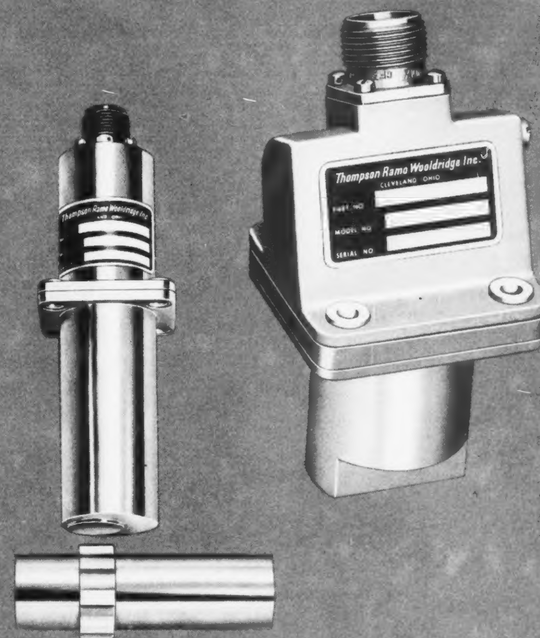
Air-vehicle electronic systems developed by the Tapco Group include highly sensitive electro-pneumatic controls capable of maintaining the speed of rotating electrical machines within plus-or-minus ¼% in either parallel or isolated operation under widely varying loads, ambient temperatures, and vibration. Tapco-developed APU speed controls provide an accuracy of one part in 100,000 (.001%) under missile environmental conditions.

At Tapco you'll find an unusual combination of electronic, electrical and mechanical skills ready to serve you.

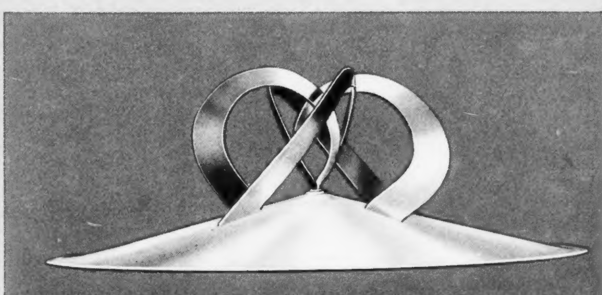




Thousands of Tapco-developed wave guide switches are used in vital aircraft and missile systems. (a) Unique power-splitting feature of rectangular wave guide switch permits switching full wave-guide power. (b) New single-pole 4-throw design has inter-channel attenuation in excess of 100 db. (c) Double-ridged wave guide switch has noise-free interlocking actuator.



Magnetic speed sensing devices developed and produced by Tapco Group for high-speed applications up to 100,000 rpm. Designs eliminate need for slip-rings, rotating permanent magnets, and complicated fly-ball mechanisms.



An advanced TRW microwave antenna design available in integrated microwave transmission subsystems from the Tapco Group. Frequency range: 1 octave. VSWR: under 2:1. Polarization: dual horizontal and vertical.

TAPCO GROUP

TRW

Thompson Ramo Wooldridge Inc.

CLEVELAND 17, OHIO

DESIGNERS AND MANUFACTURERS OF SYSTEMS, SUBSYSTEMS AND COMPONENTS FOR THE AIRCRAFT, MISSILE, ORDNANCE, ELECTRONIC AND NUCLEAR INDUSTRIES

ARS news

4 Technical Sessions Highlight Controllable Satellites Conference

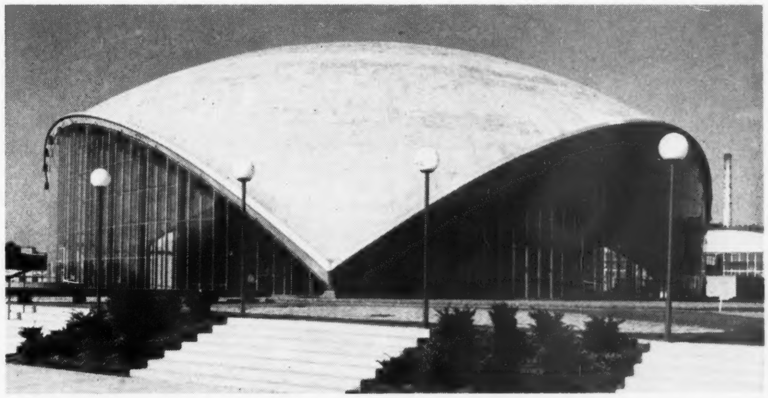
Four technical sessions and a banquet highlight the Controllable Satellites Conference, co-sponsored by ARS and the Massachusetts Institute of Technology, to be held April 30–May 1 at the Kresge Auditorium, just off the MIT campus in Cambridge, Mass., and the Statler Hilton in Boston.

The four technical sessions will be devoted to the field of satellite guidance and control, the space environment, the design of future vehicles, with emphasis on recovery, and space propulsion devices and trajectories. These four areas have been singled out by the Conference Committee, headed by Peter Rose of MIT as general chairman, because they represent fields in which research has been carried out both locally and on the national scene.

Featured speaker at the banquet, to be held Thursday evening, April 30, will be Rep. Overton Brooks, chairman of the House Committee on Science and Astronautics.

Added attractions at the conference, expected to attract an attendance of close to 500, include the opportunity to attend one of the lectures in the MIT Space Environment Symposium series (by Murray Zelikoff, director of research, Geophysics Corp. of America, on "Air Glow Phenomena in the Upper Atmosphere"), and to tour Avco Research Div., High Voltage Engineering Corp., and A. D. Little facilities in the area.

The complete program, including ARS preprint numbers for the papers, follows:



Kresge Auditorium, one of the country's architectural masterpieces, and scene of technical sessions at the Controllable Satellites Conference.

THURSDAY, APRIL 30

GUIDANCE AND CONTROL

9:30 a.m. **Kresge Auditorium**

Chairman: Walter Wrigley, Massachusetts Institute of Technology, Cambridge, Mass.
Vice-Chairman: Percy Halpert, Sperry Gyroscope Co., Great Neck, N.Y.

✦The Performance of Inertial Guidance Components on an Unstabilized Base, Henry F. Blazek, Ford Instrument Co., New York. (775-59)

✦A Guidance Approach to Earth Satellite Orbit Modification, Kenneth J. Schlager, and Robert G. Young, General Motors Corp., A. C. Spark Plug Div., Milwaukee, Wis. (776-59)

✦Terminal Guidance and Rocket Fuel Requirements for Satellite Interception, Martin L. Nason, Radio Corp. of America, Burlington, Mass. (777-59)

✦Terminal Guidance for Satellite Rendezvous, Norman E. Sears Jr. and Philip G. Felleman, Massachusetts Institute of Technology, Cambridge, Mass. (778-59)

EXTERNAL ENVIRONMENT

2:00 p.m. **Kresge Auditorium**

Chairman: Milton Greenberg, Geophysics Corp. of America, Boston, Mass.
Vice-Chairman: Norman J. Oliver, Air Force Cambridge Research Center, Bedford, Mass.

✦Atmospheric Conditions at High Altitudes from Satellite Observations, Charles A. Whitney, Smithsonian Astrophysical Observatory and Harvard College Observatory, Cambridge, Mass. (779-59)

✦Electromagnetic Radiation Environment, J. E. Kupperian, NASA Space Science Div. (780-59)

✦Higher Atmospheric Densities and Temperatures Demanded by Satellite and Recent Rocket Measurements, R. A. Minzner, Geophysics Corp. of America, Boston, Mass. (781-59)

✦The Corpuscular Radiation Environment of the Earth, S. F. Singer, Univ. of Maryland, College Park, Md. (782-59)

RECEPTION

6:30 p.m. **Imperial Ballroom Suite, Statler-Hilton**

BANQUET

7:30 p.m. **Imperial Ballroom, Statler-Hilton**

Welcome: John T. Harvell, President, ARS New England Section, Staff Engineer, A. D. Little Inc.
Introduction: James McCormack, Maj. Gen., (AF-Ret.), Vice-President, Massachusetts Institute of Technology.
Speaker: Hon. Rep. Overton Brooks, Chairman, House Committee on Science and Astronautics.

FRIDAY, MAY 1

VEHICLE DESIGN AND RECOVERY

9:00 a.m. **Kresge Auditorium**

Chairman: Tom Phillips, Raytheon Mfg. Co., Bedford, Mass.
Vice-Chairman: Paul Sandorff, Massachusetts Institute of Technology, Cambridge, Mass.

✦Application and Uses of Satellites, George Brader, ARPA, DOD, Washington, D.C. (783-59)

✦Controlled Recovery of Non-Lifting Satellites, R. W. Detra, F. R. Riddell, and P. H. Rose, Avco Research Lab., Everett, Mass. (784-59)

✦The Use of Aerodynamic Lift During Entry Into the Earth's Atmosphere, Lester Lees, Fred W. Hartwig, Clarence B. Cohen, Space Technology Lab., Los Angeles, Calif. (785-59)

✦Concepts Influencing the Selection of a Configuration for Atmospheric Re-entry, Donald I. Kepler, Lockheed Missile and Space Div., Palo Alto, Calif. (786-59)

✦The Feasibility of Aerodynamic Attitude Stabilization of a Satellite Vehicle, John K. Waul, Douglas Aircraft Co., Santa Monica, Calif. (787-59)

PROPULSION AND TRAJECTORIES

2:00 p.m. **Kresge Auditorium**

Chairman: Arthur Kantrowitz, Avco Research Lab., Everett, Mass.
Vice-Chairman: E. S. Taylor, Massachusetts Institute of Technology, Cambridge, Mass.

✦Propulsion Systems for Controlling Satellite Orbits, La Verne E. Klund, Pratt & Whitney Aircraft Div.; Theodore Edelbaum, United Aircraft Research Dept.; William H. Podolny, Pratt & Whitney Aircraft Div.; United Aircraft Corp., Hartford, Conn. (788-59)

✦Ion Rockets for Small Satellites, Russell N. Edwards and Harold Brown, General Electric Co., Flight Propulsion Lab., Evendale, Ohio. (789-59)

✦Rocket Systems for Satellite Attitude Control, W. Sanscrainte and D. C. Schiavone, Bell Aircraft Corp. Buffalo, N. Y. (790-59)

✦The Arc Heated Plasma Thrust Chamber, Mac C. Adams, and M. Camac, Avco Research Lab., Everett, Mass. (791-59)

✦The Correction of Epoch Error in Circular Orbits, Lawrence J. Berman, Massachusetts Institute of Technology, Cambridge, Mass. (792-59)

On the calendar

1959	
April 5–10	5th Nuclear Congress of Engineers Joint Council, Cleveland Auditorium, Ohio.
April 7–10	American Welding Society 40th Annual Technical Meeting and Welding Exposition, Hotel Sherman and International Amphitheatre, Chicago.
April 12–19	World Congress of Flight, sponsored by Air Force Assn., Las Vegas, Nev.
April 16–17	Reliability Symposium of the Boston Section, American Society for Quality Control, at Statler-Hilton Hotel, Boston, Mass.
April 22–24	3rd Annual Technical Meeting of the Institute of Environmental Engineers, LaSalle Hotel, Chicago.
April 29–31	New Developments in Metals Engineering and Related Fields, ASME, Albany, N.Y.
April 30–May 1	**ARS Controllable Satellites Conference, MIT, Cambridge, Mass.**
May 4–6	1959 Southern Metals Conference, ASM Savannah River Chapter, Bon Air Hotel, Augusta, Ga.
May 4–7	5th ISA National Instrumentation Flight Test Symposium, Seattle, Wash.
May 6–8	1959 IRE Seventh Region Conference and Electronics Exhibit, Univ. of New Mexico, Albuquerque, N.M.
May 20–22	Society for Experimental Stress Analysis 1959 Spring Meeting and Exhibition, Sheraton Park Hotel, Washington, D.C.
May 21–27	Int'l Scientific Convention and Exhibition, Institution of Electrical Engineers, Earls Court, London, England.
May 25–27	Japanese Rocket Society 1959 Int'l Symposium on Rockets and Astronautics, Tokyo.
May 25–27	**National Telemetering Conference, co-sponsored by ARS, AIEE, IAS, and ISA, Denver, Colo.**
June 8–9	Industry Missile and Space Conference, Aero Club of Michigan, Sheraton-Cadillac Hotel, Detroit.
June 8–11	**ARS Semi-Annual Meeting and Astronautical Exposition, San Diego, Calif.**
June 11–13	1959 Heat Transfer and Fluid Mechanics Institute, Univ. of Calif., Los Angeles.
July 20–21	**ARS Propellant Thermodynamics and Handling Conference, Ohio State Univ., Columbus, Ohio.**
July 24–26	AIEE Air Transportation Conference, in conjunction with 1959 Summer and Pacific General Meeting, Olympic Hotel, Seattle, Wash.
Aug. 9–12	ASME-AICE Heat Transfer Conference, Univ. of Connecticut, Storrs, Conn.
Aug. 24–26	**ARS Gas Dynamics Symposium, Dynamics of Conducting Fluids, Northwestern Univ., Evanston, Ill.**
Aug. 27–29	American Physical Society 1959 Summer Meeting in the West, Univ. of Hawaii, Honolulu.
Aug. 28–29	British Commonwealth Space Flight Symposium, Westminster, London.
Aug. 31–Sept. 2	4th Int'l Symposium on Free Radical Stabilization at National Bureau of Standards, Washington, D.C.
Aug. 31–Sept. 5	**10th Annual International Astronautical Federation Congress, Westminster, London.**
Sept. 22–24	Industrial Nuclear Technology Conference, co-sponsored by Illinois Inst. of Tech., at Morrison Hotel, Chicago.
Sept. 24–25	**ARS Solid Propellants Conference, Princeton Univ., Princeton, N.J.**
Oct. 6–9	Int'l Symposium on High Temperature Technology, sponsored by Stanford Research Institute, at Asilomar, Calif.
Oct. 7–9	ASME-AIME Solid Fuels Conference, Cincinnati, Ohio.
Oct. 12–14	National Electronics Conference, Co-sponsored by Illinois Inst. of Tech., at Hotel Sherman, Chicago.
Oct. 26–28	IRE Professional Group East Coast Conference on Aeronautical and Navigational Electronics, Baltimore, Md.
Oct. 26–30	1959 National Conference of the Society of Photographic Scientists and Engineers, Edgewater Beach Hotel, Chicago.
Oct. 28–29	6th Annual Computer Applications Symposium, sponsored by Illinois Inst. of Tech., at Morrison Hotel, Chicago.
Nov. 16–20	**ARS 14th Annual Meeting and Astronautical Exposition, Washington, D.C.**
Nov. 16–20	5th Int'l Automation Exposition and Congress, N.Y. Trade Show Bldg., New York, N.Y.
1960	
Jan. 28–29	**ARS Solid Propellants Conference, Princeton Univ., Princeton, N.J.**
Aug. 31–Sept. 7	10th Int'l Congress of Applied Mechanics, Congress Bldg., Stresa, Italy.

July 20-21 New Dates for Propellants Conference

The ARS Propellant Thermodynamics and Handling Conference, announced for May 12–13 in the March ASTRONAUTICS, has been rescheduled for July 20–21. Site will be Ohio State Univ. in Columbus, Ohio.

The conference, held under the technical cognizance of the ARS Propellants and Combustion Committee, will be co-chaired by Alexis Lemmon of Battelle Memorial Institute and Loren Bollinger of Ohio State Univ.

Subjects covered will include calculations methods on propellant transport and thermodynamic properties, and methods of handling propellants, particularly fluorine, announces John Sloop of NASA's Lewis Research Center, chairman of the Propellants and Combustion Committee.

Meetings will be held on the Ohio State Univ. campus. The campus will also provide room accommodations for registrants. The complete program will be mailed to all members next month.

Papers should be submitted to Loren Bollinger, Ohio State Univ., Columbus, Ohio.

Registration Forms Available For 10th IAF Congress

ARS members intending to go to the 10th IAF Congress in London Aug. 31–Sept 5 should write to the ARS office in New York for official registration forms. Address requests to Meetings Manager, AMERICAN ROCKET SOCIETY, 500 Fifth Ave., New York 36, N.Y.

All those interested in a low-cost charter flight to the Congress are requested to indicate such interest when requesting registration forms.

ARS Chrysler, Thiokol Student Award Competition Opens

The 1959 ARS student awards competitions are now open. Two separate competitions are being held, with all entries to be judged by the ARS Awards Committee, headed by Krafft Ehricke of Convair-Astronautics.

The first, and older of the two awards, is the $1000 ARS-Chrysler Corp. Award, initiated in 1956, to be presented to the undergraduate or team of undergraduates submitting the paper on any subject related to astronautics judged best by the Committee.

The second, initiated last year, is the $1000 ARS-Thiokol Chemical Corp. Award, which will go to the graduate student or team of graduate students presenting the best paper on a similar subject.

Deadline date for completed manuscripts for both competitions is Sept. 1. Both awards will be presented at the 1959 ARS Honors Night at Sheraton Park Hotel, Wash., D.C., Nov. 18.

All contestants must submit entry forms along with manuscripts. Entry forms may be obtained by writing to: 1959 Student Paper Competitions, ARS, 500 Fifth Ave., New York 36, N.Y., specifying the competition the writer is interested in.

Dayton Section Sponsors Space Education Week

The Dayton section will hold a Space Education Week April 26 to May 1 for students, teachers, parents, and the public-at-large of the city. Taking the theme, "The Peaceful Use of Space," the Dayton Space Education Week will feature workshops, lectures, field trips, talks before local civic groups, and a concluding banquet. The Dayton section hopes to make this effort toward community education a model for other sections of ARS.

AGARD Panel to Meet On Propellant Chemistry

The Combustion and Propulsion Panel of the Advisory Group for Aeronautical Research and Development will sponsor an unclassified meeting on "Chemistry of Propellants" during the week of June 8 at the NATO Headquarters Building in Paris. The meeting will serve to help NATO countries inaugurate modest research programs.

A Growing Society

Wernher Von Braun, new ARS membership chairman, and Rodney Stewart, president of the Alabama section, show a grasp of their business as they shake hands over recent membership totals.

Astronautical Exposition Space Going Fast

More than 65 companies have already signed up for space at the two Astronautical Expositions planned by ARS this year. The Western exposition will be held June 9–11 in conjunction with the Semi-Annual Meeting at the El Cortez Hotel in San Diego, while the Eastern show Nov. 17–19 will be a highlight of the ARS 14th Annual Meeting at the Sheraton-Park Hotel in Washington.

Exhibitors who have contracted for the Western show are: Accessory Products Co.; Aeronutronic Systems; Aerojet-General; Aeroquip Corp.-Marman Div.; Autonetics Div. of North American Aviation; Beckman & Whitley; Blaw-Knox Co.; Brush Instrument-Clevite Corp.; Burroughs Corp.; Callery Chemical Co.; Convair-Astronautics; Deutsch Fastener Corp.; Douglas Aircraft Co.; Food Machinery & Chemical Corp.; Futurecraft Corp.; Garrett Corp.; General Electric; International Tel. & Tel. Corp.; Walter Kidde & Co.; Marquardt Aircraft; McCormick Selph Associates; Minnesota Mining & Mfg. Co.; Norris-Thermador Corp.; Raytheon Mfg. Co.; Resolin, Inc.; Robertshaw-Fulton Controls Co.; Rocketdyne; Solar Aircraft Co.; Thiokol Chemical Corp.; Western Gear Corp.; Wyman Gordon; John Wiley & Sons; and Zero Mfg. Co.

The following companies have already signed up for space at the Eastern exposition: Acoustica; Aeronutronic Systems; Aeroquip Corp.; Atlantic Research Corp.; Burroughs Corp.; Callery Chemical Co.; Chance Vought Aircraft; Deutsch Fastener Corp.; Douglas Aircraft Co.; Experiment Inc.; Ford Instrument Co.; Futurecraft; Garrett Corp.; Grumman Aircraft Corp.; General Electric; Holex Inc.; International Tel. & Tel. Corp.; Johns-Manville; Linde Co.; Walter Kidde & Co.; The Martin Co.; Marquardt Aircraft Co.; McCormick Selph Associates; Rocketdyne; Raytheon Mfg.; Resistoflex Corp.; Republic Aviation; Shell Oil Co.; Thompson Ramo Wooldridge—Tapco Group; H. I. Thompson Fiber Glass Co.; Thiokol Chemical Corp.; Westinghouse Air Arm Div.; Westinghouse Electronics Div.; John Wiley & Sons; and Wyman-Gordon Co.

Five More Companies Become ARS Members

Five more companies have become corporate members of the AMERICAN ROCKET SOCIETY. The companies, their areas of activity, and those named to represent them in Society activities are:

All American Engineering Co., Wilmington, Del., engaged in R&D of aerial recovery systems; missile guidance subsystem electromechanical components; aircraft and drone launching and arresting gear equipment. Representing the company in ARS are D. B. Doolittle, vice-president of engineering and production; R. B. Janney, chief engineer; C. J. Daniels, director of government projects; M. C. Wardle, chief of preliminary design; A. A. du Pont, assistant to director of government projects.

Bramley Machinery Corp., Edgewater, N. J., manufacturer of Bramley Beken Horizontal Shaft Mixers and Bramley Beken Planetex Vertical Mixers (Change Can Type) for mixing-dispersing and kneading propellant fuels and like products. Representing the company are B. M. Halper, president; L. A. Thomson, sales engineer; and R. B. Wuensch, engineer.

Raytheon Mfg. Co., Waltham, Mass., holds prime contracts for the Army Hawk and Navy Sparrow III, and has interest in all phases of missiles including control, guidance, aerodynamic structures, propulsion, etc. Named to represent the company in ARS are V. W. Wall; Harold Hart; Fred Youngren, manager of aerodynamics, Bedford, Mass.; T. L. Phillips, manager of Bedford Lab; Mike Fossier, rocket propulsion group, Bedford.

Todd Shipyards Corp., New York, N. Y., engaged in combustion, flame propagation, high temperature materials, fuels, and propellants. Designated to represent the company are J. T. Gilbride, president; J. D. Reilly Jr., executive vice-president; R. W. Bowes, vice-president; B. W. Winchell, engineer; and J. A. Hayes Jr., assistant general manager.

United States Rubber Co., Naugatuck, Conn., engaged in research on fuels, binders, insulators, manufacture of polymeric binders and insulators. Representing the company are E. L. Borg, manager of synthetic rubber research; P. O. Tawney, group leader of organic chemical research; G. E. Kelsheimer, group leader of footwear divisional development lab, Mishawaka, Ind.; R. D. Gilbert, group leader of synthetic rubber research; W. S. Coe, director of R&D, Naugatuck Chemical Div.

ARS 1959 Paper Deadlines

Date	Meeting	Location	*Deadline
April 30–May 1	Controllable Satellites Conference	MIT	Past
May 25–27	National Telemetering Conference	Denver, Colo.	Past
June 8–11	Semi-Annual Meeting	San Diego, Calif.	April 27
July 20–21	Propellant Thermodynamics & Handling Conference	Ohio State Univ.	May 18
Aug. 24–26	Gas Dynamics Symposium	Northwestern Univ.	June 22
Aug. 31–Sept. 5	10th IAF Congress	Westminster, London	May 15
Nov. 16–20	14th Annual Meeting	Washington, D.C.	Aug. 17
1960			
Jan. 28–29	Solid Propellants Conference	Princeton Univ.	Nov. 16

* For reviewed and approved manuscripts in the New York office. Subtract 30 days for unsolicited papers that must go through the reviewing procedure and 60 days for abstracts submitted for consideration. Send all papers and abstracts to Meetings Manager, ARS, 500 Fifth Ave., New York 36, N.Y.

SECTIONS

Antelope Valley: The January meeting had as its speaker **K. W. Jeremiah,** manager of Convair Astronautics Operations, Edwards AFB. His extensive background in Convair's Atlas Program enabled him to present an outstanding picture of ICBM testing. Those attending were amazed at the close cooperation and coordination of the many associate contractors, the diversity of manufacturers in the Atlas program, and the complexities of an actual firing test. A movie was shown which highlighted the talk.

The year's first dinner meeting was held jointly with the local IAS section in February. Approximately 185 husbands and wives gathered at the Antelope Valley Country Club to hear AF Maj. **Ben Bellis** of BMD speak on "The Air Force in Space." Maj. Bellis' talk was highlighted by outlines of past, present, and future AF projects dealing with space exploration and astronautics. Of particular interest were the slides and movies covering AF lunar probe and Atlas Score launchings at the Atlantic Missile Range.

The March meeting was a classified session, with **J. Carnes** of Thiokol Corp. speaking on "Large Solid Propellant Rockets."

The section has given birth to a new quarterly publication called "Rocket Topics" to acquaint people with its activities.

—**H. E. Coyer**

Central Texas: New officers elected early in the year were J. A. Crask, president; W. G. Haymes, vice-president; C. H. Herty, secretary; and G. M. Kyser, treasurer. Soon afterward, Crask was forced to tender his resignation, since he planned to leave the area. W. G. Haymes succeeded as president and P. Albanese was elected vice-president.

In an evening meeting early in February, members and guests with clearance gathered at the First National Bank in Waco to see this program of films: "World's Shortest Runway," on zero-length launching of F-100 aircraft; "Megaboom Powered Sled," on the installation and firing of Megaboom booster on a NOTS sled; "Target for Tomorrow—Ready Today," on flight testing of the Temco Teal

Kansas City Section Chartered

Members and guests of the Kansas City section gather about ARS President John P. Stapp on charter night. Half of the new section's members follow astronautics by day at the Westinghouse Aviation Gas Turbine Div.

XKDT-1 rocket-powered drone; and "Rocket Power," a review of Rocketdyne's progress in liquid rocket engine development, classified Confidential.

Cleveland-Akron: At a January dinner meeting held jointly with the local ASME section, ARS President **John P. Stapp** presented the Fenn College Student Chapter with its charter. Later, as speaker of the evening, Col. Stapp gave an interesting talk on the effects of space environment on man, and showed a film of some recent zero-gravity experiments at WADC.

—Harold W. Schmidt

Columbus: The year's first meeting in January was attended by 88 members and guests who had the pleasure of hearing guest **John D. Kraus,** professor of electrical engineering at Ohio State Univ. and director of its Radio Observatory, talk on "Exploring Space by Radio." With the aid of slides, Dr. Kraus explained his system of tracking satellites by the reflection of radio signals from the ionized trail following a vehicle in space. He delved into signal sources in space, their origins, and the conclusions which can be drawn from them.

The emphasis then shifted to a new radio telescope being built under the direction of Dr. Kraus and his associates on ground near Perkins Observatory just south of Delaware, Ohio. Slides were shown of various phases of construction of this behemoth. The principle of operation is the reflection of signals from a huge flat surface (approximately 350 ft long by 70 ft high) to a huge parabolic screen of similar dimensions. This parabola in turn focuses the signal into a receiving horn, from which it is fed into high gain amplifiers for recording.

To end his talk, Dr. Kraus played a tape of signals from some of the satellites, taken with his tracking system, and explained in detail the Doppler shift effect.

The February meeting, held jointly with the Columbus section of IRE, heard guest **R. D. Van Nest** of Boeing Airplane Co. speak on "The Role of Bomarc in Air Defense." With the aid of slides, he recounted the history of Bomarc development, explained the functioning of its guidance system in conjunction with Sage, and described the complete launching complex, also shown in a movie. He also explained that an anti-jamming system has been developed for Bomarc which allows it to be launched and directed in large numbers for area defense. This presentation prompted a vigorous question-and-answer period.

New officers of the section will step up in March, when the guest speaker will be ARS President **John P. Stapp.**

—Dean L. Pendleton

Detroit: The section was honored at its February meeting by a special visit from ARS President **John P. Stapp,** who talked on "The Problems of Manned Space Flight" before a group of several hundred members and wives at the Veterans Memorial Building. Col. Stapp discussed in detail the effects of the Van Allen radiation belt, feeding and nutrition problems, the psychological effects of weightlessness over long periods, and other physical and emotional reactions man must recognize and accept before he is ready for prolonged space exploration. Many of these problems are of course now undergoing investigation at WADC and at Holloman. His talk was supported by an excellent 16-mm motion picture and slides taken during actual experiments.

On March 12, the Detroit section played host to one of the largest turnouts in its history. Under joint sponsorship with IAS and the State Bar of Michigan, the section offered a public forum on "The Techno-Legal Aspects of Space Exploration." Moderating this special four-man panel discussion was Andrew G. Haley, president of the IAF and ARS general counsel. Representing industry were Lovell Lawrence Jr. and Robert P. Erickson of Chrysler Corp., while G. Vernon Leopold and Allison L. Scafuri represented the Michigan State Bar space law subcommittee.

—Dan P. Lutzeier

National Capital: The section is aggressively developing membership in preparation for the ARS Annual Meeting in Washington next November. A record attendance was attracted by the January luncheon for a briefing on the missile situation by noted editors and correspondents. The panel of speakers included **Vern Haugland,** aviation editor for the Associated Press, who outlined the pending schedule of rocket firings at Cape Canaveral; **Tom MacNew,** editor of *Aircraft & Missiles Manufacturing,* who reviewed a dozen leading missile projects; **Vincent F. Callahan Jr.,** editor of the *Washington Space Letter,* who spoke on NASA; and **John R. Botzum,** Washington correspondent of *Steel Magazine,* who reported on the missile budget, predicting that the annual outlay for production, as apart from R&D, will double in five years. The program was arranged by Kendall K. Hoyt of the Assn. of Missile & Rocket Industries.

New York: Officers elected for the new term were R. Frazee, president; T. P. Torda, vice-president; P. Rountree, secretary; and J. Taylor, treasurer.

The February meeting featured a talk by **Robert Gross** on propulsion systems for space travel. Dr. Gross, chief research engineer for Fairchild Engine Div. of Fairchild Engine and Airplane Corp., recently received a senior postdoctoral National Foundation Fellowship, which will take him for a year's study of plasma physics to Princeton Univ. and the Univ. of California. Dr. Gross discussed chemical, nuclear, and electrical propulsion systems, with special emphasis on electromagnetic means of producing thrust, and compared the requirements of several systems for a trip to Mars.


what is
temperature?

At North Texas Section's Annual Meeting

At the annual banquet meeting of the North Texas section, new president John A. Kerr (standing) introduces Dean W. M. Longnecker (seated extreme left) of SMU, who discussed "Our Present Educational Mess."

Niagara Frontier: New officers were installed at a dinner meeting in January. They are Clayton Williams, president; John C. Magalhaes, vice-president; Myron Ettus, treasurer; Robert Roach, corresponding secretary; and Seth Clack, recording secretary. Following the introduction of new officers, guest **Austin C. McTigue,** professor of physics and chairman of the Dept. of Physics at Canisius College, spoke on observations of atomic tests at the Nevada Test Site. He commented on geological and radiological aspects of atomic bomb explosions with the aid of a number of fine slides.

—Paul Carpenter

North Texas: More than 100 members and guests attended the annual banquet in January to witness the installation of new officers–John A. Kerr, president; R. N. Rioux, vice-president; Ron E. Krape, secretary; and J. Haden, treasurer–and to hear Dean **W. M. Longnecker** of SMU give a thought-provoking speech on "Our Present Educational Mess." He asserted that we need to redefine the purpose of public schools if we hope to remain technically competitive with the Soviet Union. Outgoing president Charles Crabtree was installed as a member-at-large to ARS at the meeting. New president John Kerr stated that the section will start a vigorous membership campaign, and plans a broadened meeting schedule.

—W. H. Bender

Pacific Northwest: The January meeting, held in the Health Sciences Auditorium at the Univ. of Washington, included presentation of officers for the calendar year 1959–George W. Hettrick, president; D. M. Van Ornum, vice-president; Regis A. Hacherl, secretary; and Joseph B. Heineck, treasurer–and a talk on "A Martian Explorer" by **Henry K. Hebler** and **Richard D. White** of the Systems Management Office, Boeing Airplane Co. The design of a vehicle capable of reconnoitering the planet Mars is one of the projects being investigated by Boeing's System Management Office.

The speakers noted that, according to the Boeing design, the "Martian Explorer" would be constructed at a space station in orbit around the earth. The system would be propelled by an ion accelerator using cesium as the ion source and solar batteries as the source of electrical power. The time required for the vehicle to be launched, orbit Mars, and return to the space station was estimated at about $3^1/_2$ years. In the course of the trip, the vehicle would observe the surface of Mars and report its findings to a station on earth.

—Regis A. Hacherl

Palm Beach: Before some 300 members and prospective members at a January dinner meeting in the Hotel Pennsylvania, **Krafft A. Ehricke,** assistant to the chief engineer of Convair-Astronautics and member of the ARS national board, presented the charter to the president of this new section, Henry J. Barten, and then installed the remaining officers: R. W. Hill, vice-president; Stanley A. Mosier, secretary; and Wayne H. Patterson, treasurer. Later in the evening, Ehricke gave a brilliant talk on "Astronautic Developments in the Near Future," with emphasis on recent Russian and U.S. attempts to hit the moon.

At the February meeting, **Wallis C. Rainwater,** chief engineer for powerplant testing and assembly at ABMA's Missile Firing Laboratory at Titusville, Fla., discussed "Mechanics and Timing Concerning Missile Firing Tests at Cape Canaveral." He related some of his experiences in over 50 Canaveral firings, including three of the Explorer satellites. The talk was well-received by the more than 50 members in attendance.

The section is sponsoring an extensive educational program in Palm Beach County. Classes on all phases of rocketry have been organized by members of the section for high school and junior college teachers of science and mathematics. Negotiations are also underway to present a series of rocket-science lectures on local television stations. In this manner, the section hopes to reach local students at school and in the home.

—Stanley A. Mosier

Pittsburgh: At an evening meeting early in February, members and guests met in the Mellon Institute to hear **Joseph Maltz,** assistant chief of BuAer's materials section, discuss "Construction Materials for High Speed Aircraft, Missiles, and Spacecraft."

Kansas City: Despite miserable weather, which all but shut down Kansas City, approximately 160 members and guests attended the January 20 meeting to see ARS President **John P. Stapp** present the Section with its charter, and to hear him and Capt. **Joseph Kittinger** discuss the earth's radiation belts and weightlessness as current problems of space research. By way of introduction, Col. Stapp cited the goal of the astronauts. "There is," he said, "the great challenge of following the pioneering of the telescope by traveling the path from the earth to the moon, to other planets, and beyond." He told the new section that it is the purpose of the national organization to promote knowledge of the field of astronautics with every means at its command. Alan Pittaway, first section president, accepted the charter for the section and pledged vigorous action locally and in the nationwide programs of the Society.

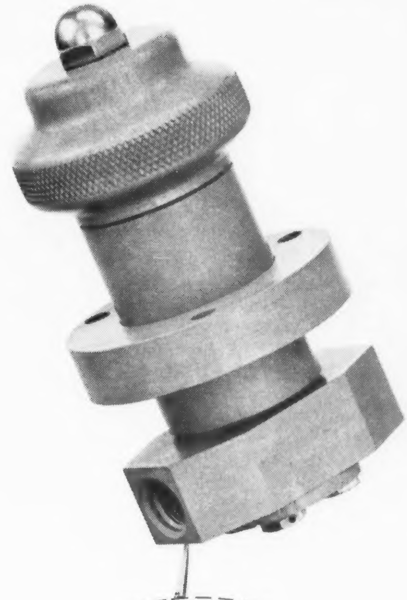
—Charles R. Burke

Southern California: Recently elected officers of the section are William J. Cecka Jr., president; William L. Rogers, vice-president; Herb B. Ellis, secretary; and Frank A. Coss, treasurer. Don L. Armstrong was chosen chairman-elect of the section.

The first meeting of the 1959 session was held at the Institute of Aeronautical Sciences Building on January 29. **Comdr. Robert Freitag,** USN,

Clary introduces a new concept in valve design...

top-performing economical regulators



Here at last...hand-loader type regulator valves that are economical in the true sense of the word!

First, they are far less expensive than regulators of comparable quality and performance specifications. This low price is made possible by a unique, simplified design and by Clary's years of design and manufacturing experience.

Second, their ease of maintenance saves valuable man-hours. There's no need to remove the entire unit should failures occur – a simple replacement of the "O" ring seal does the job quickly and easily.

Third, because they are adjustable over an extremely wide range of pressures, you can use them in a variety of applications.

To find out more about these exceptional regulators, send for technical bulletin #CD-150. And whenever precision, reliability and versatility are factors in your plans, call on Clary for complete services.

HAND-LOADER PRESSURE REGULATOR

Port Size: 1/4 Tube Per AND 10050

Pressure Characteristics:

A. Operating	B. Proof
Upstream 4000 PSIG Max.	Upstream 6000 PSIG
Downstream 3000 PSIG Max.	Downstream 4500 PSIG

Service: Air, Nitrogen, Helium

Flow Area: Fully Open Thru Area .003 in.^{2}

Ambient Temperature Range: –65°F. to +160°F.

Lubrication: Dow-Corning DC-11 Silicone M.L.– L– 4343 Grease Unless Otherwise Specified.

Weight: 1.2 Lbs.

Clary is one of the nation's largest manufacturers of rocket and missile valves. Other devices include: ABSOLUTE PRESSURE REGULATOR that maintains an outlet pressure of 18½ to 20 PSIA with variations in flow rate from 3 to 350 SCFM under 30 to 100 PSIA inlet pressure and –65°F. to +350°F.; and DIFFERENTIAL PRESSURE REGULATOR that maintains an outlet pressure of 6 PSIG ±.25 with flow variations from 3 to 160 SCFM under 10 to 250 PSIG inlet pressure and –65°F. to +350°F.

Clary

Clary Dynamics
San Gabriel, California
Manufacturers of business machines, electronic data-handling equipment, aircraft and missile components

gave a classified lecture on the Pacific Missile Range, its importance, its objective, and its long-range planning. The meeting was particularly well attended, and showed the importance which local industry also attaches to the new range.

Section president William J. Cecka Jr. announced that the section now has over 2300 members, with representatives in over 130 plants in the area.

—**Eric Burgess**

Wichita: The following new officers were presented at the January dinner meeting: Alex Petroff, president; Edward Manspeaker, vice-president; Dean Burleigh, secretary; and Harold Roberts, treasurer.

STUDENT CHAPTERS

Alabama Polytechnic Institute: The chapter has been widening its knowledge of career oportunities in rocketry by inviting knowledgeable guests from the locality to discuss this subject. It contributed exhibits to the Institute's open house last year in cooperation with the Institute's school of aeronautical engineering. The group also made a tour of Redstone Arsenal last year.

—**Darryl Holder**

Drexel: With the aid of material solicited from rocket, missile, and aircraft companies, the chapter is building an exhibit which will be made available to the student body. Some time in spring, the chapter expects to tour the Naval Air Rocket Test Station at Lake Denmark. At the last meeting, guest speaker **O. D. Reed** of Thiokol discussed recent advances in rocket propulsion systems, and films were shown of a Baltimore rocket society's activities.

—**Eugene J. Boyle**

Newark College of Engineering: After a year's activity, the chapter has a new roster of officers: David Broome, president; Walter Buttkus, vice-president; Arthur Hecht, treasurer; Robert Sorensen, recording secretary; and James Vojcik, corresponding secretary. Three of the four major departments of the school are represented by these officers.

During the past year, through research, movies, speakers, and projects, the members advanced greatly in their knowledge of the fundamentals of the field. A wind tunnel demonstration by the school's Mechanical Engineering Dept. helped members from other departments realize some of the problems of aerodynamic design. Literature obtained from Bell Aircraft and Rocketdyne also helped us a great deal.

The highlight of the year, of course, was the national meeting at the Hotel Statler-Hilton and the student dinner given by Thiokol. For the seniors who attended, this event provided the incentive to join the missile industry.

Future plans call for more action along project lines, continued efforts for movies, speakers, and research literature, and closer cooperation with the other college chapters in this vicinity.

Parks College: In a meeting in February, members re-established the chapter's technical library, voted to rewrite the chapter constitution, planned to invite speakers for forthcoming meetings, and saw three movies—"Operation Sandy," "The Sky Is No Limit," and "The Rocket."

—**Norbert J. Kulpa**

Student Chapter Chartered at Fenn

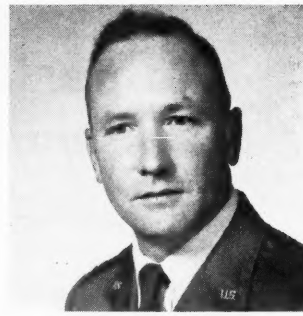
ARS President John P. Stapp presents charter to Chairman Allen J. Smith Jr. of the new Fenn College Student Chapter at a recent meeting of the Cleveland-Akron Section.

TECHNICAL COMMITTEES

Test Facilities and Support Equipment: AF Col. Harold W. Norton, director of captive missile testing, Edwards AFB, has been named chairman of the newly formed ARS Test Facilities and Support Equipment Committee.

A graduate of West Point and the USAF Institute of Technology, Col. Norton has seen prior service at Holloman AFB, as executive officer and director of test operations; at Patrick AFB, as commander of the 6541st Range Squadron; and with the AF Ballistic Missile Div., before being assigned to his present post.

Members of the committee are: B. L. Dorman, Aerojet; R. A. Schmidt, Edwards AFB; and R. F. Gompertz,



Col. Harold W. Norton

Rocketdyne, appointed for two-year terms; and K. K. McDaniel, Boeing; Robert Kendall, Arthur D. Little Co.; Harold Lipchik, AMF; John C. Palmer, NASA; and E. A. Nielsen, Chrysler, all named for one-year terms.

Non-Propulsive Power: A. M. Zarem, president of Electro-Optical Systems, Inc., has been appointed chairman of the Non-Propulsive Power Technical Committee. A former visiting professor of engineering at the Univ. of California, where he taught the only formal course ever given at a university in solar energy, Dr. Zarem was one of the founders of the Assn. of Applied Solar Energy. From 1948 to 1955, he was with Stanford Research Institute, as assistant director and manager of its Southern California Div.

Named by Dr. Zarem to serve on the committee are: Maj. W. G. Alexander, AF Directorate of Astronautics; Lt. Col. G. M. Anderson, AEC Aircraft Reactor Branch; Gordon Banerian, Aerojet; Charles W. Burrell, Lockheed Missile Systems Div.; Walter Deacon, Vickers; Paul H. Egli, NRL; R. E. English, NASA Lewis Research Center; John H. Huth, Rand Corp.; K. P. Johnson, Martin Co.; Cecil G. Martin, Thompson Products; R. W. McJones; Norton H. Nelson, North American Aviation; Dean A. Rains, Propulsion Research Co.; Paul Rappaport, RCA Labs Div.; Nathan Ruder, Boeing Pilotless Aircraft Div.; N. W. Snyder, ARPA; Ernst Stuhlinger, Redstone Ar-

A. M. Zarem

senal; J. R. Wetch, Atomics International; B. J. Wilson, NRL; Ernest Yeager, Western Reserve Univ.; and Eugene B. Zwick, Sundstrand Turbo.

Hydromagnetics: Milton U. Clauser, vice-president and director of the Physical Research Laboratory, Space Technology Laboratories, has been named chairman of the ARS Hydromagnetics Committee. Ali B. Cambel, Northwestern Univ., will serve as vice-chairman. Committee members are: Rolf Buhler, Giannini Research Lab.; Arthur Kantrowitz, Avco; Rudolf X. Meyer, STL; Joseph Neuringer, Republic Aviation; Allen E. Fuhs, Northwestern Univ.; Mark L. Ghai, GE; R. H. Fox, Univ. of California; John C. Evvard, NASA Lewis Research Center; Robert Boden, Rocketdyne; and Milton Slawsky, AFOSR.

Milton U. Clauser

CORPORATE MEMBERS

Aerojet-General renamed its ordnance engineering division at Frederick, Md., the Atlantic Div. An R&D group established about two years ago, this division is working on automatic parcel-post sorting systems for the Post Office Dept., underwater communication projects for the Navy, and Firetrac airborne electronic miss-distance equipment for the USAF-Lockheed drone program. Aerojet's new Antisubmarine Warfare Div., formed to handle the multimillion dollar Navy contract for final development and production of a new homing torpedo, will expand the company's research in submarine detection, underwater communication, ocean surveillance, and related activities. The Atlantic Div., and in particular the staff headed by John V. Atanasoff, will work on sound and communication problems in this torpedo program.

American Potash & Chemical will build a commercial plant costing about $800,000 at its main Trona facilities for the production of boric oxide, a raw material in the manufacture of high energy fuels and other industrial products.

Atlantic Research began occupying its $1 million permanent headquarters building in the Virginia suburbs of Washington, D. C. This 85,000 sq ft combination main office and laboratory is on a 46-acre site.

NAA Autonetics Div. has established a human factors engineering group headed by Kenneth S. Teel.

Convair-Astronautics Div. of General Dynamics has let contracts for more than a million dollars of new construction as part of its expansion program for this year. Convair Instruments has moved into new and larger quarters in San Diego.

Hoffman Electronics established its new Science Center Div. in Santa Barbara, Calif., pending construction of a permanent facility. The company also leased a three-story downtown Los Angeles building to expand the work and service of its Laboratories Div.

Hughes Aircraft purchased the assets of Vacuum Tube Products Company, Inc., of Oceanside, Calif., which under Hughes will continue to produce and market its lines of vacuum tubes, precision electronic welding equipment, diodes, gauges, controls, and timers with the same management in existing plants.

ITT dedicated a new plant in Roanoke, Va., which as part of its Component Div. will manufacture traveling-wave and image-storage tubes. ITT expects the plant to employ more than 200 persons by the end of the year.

Linde Div. of Union Carbide will build a new plant capable of producing 100 million cu ft of oxygen and nitrogen a month near Redstone Arsenal by early 1960.

Marquardt's recently acquired Cooper Development Div. was one of the 17 firms honored by the Army with a public service plaque for its contributions to the Explorer I project.

Northrop Aircraft has acquired Page Communication Engineers Inc., as a wholly-owned subsidiary, to extend its work in long range radio communications. Page recently completed the world's first intercontinental network based on scatter-propagation techniques.

RCA Semiconductor and Materials Div. will expand its headquarter plant at Somerville, N. J., from 177 to 267 thousand sq ft to make possible increased production of high performance transistors for special applications in computers and other electronic equipment.

Solar Aircraft, as part of a program of expanded facilities, has ordered a brazing furnace capable of handling honeycomb panels roughly 8 x 14 ft. This is in addition to the recently announced underground furnace for brazing and heat treating.

Sylvania Electric Products opened the 30,000-sq ft new headquarters for its Electronic Systems division next to the Waltham Labs of the Systems group. With 20,000 sq ft for a pilot line, this facility will work on B-52 and B-58 countermeasure subsystems.

Western Gear Corp. will add a $350,000 quality control facility to its Precision Products Div. on the company's 26-acre Lynwood, Calif., property. Air-conditioned, temperature-controlled, and dust-free, this facility will house precision standards for gauges and other precise equipment.

Details of Commonwealth Space Flight Symposium

Additional details on the Commonwealth Space Flight Symposium, to be held at Church House, Westminster, London, Aug. 27–28, immediately prior to this year's IAF Congress, have been released by the British Interplanetary Society, which is setting up the meeting.

A Commonwealth Astronautical Committee was established at the IAF Congress in Amsterdam last year to assess the possibility that Commonwealth Countries could engage in joint activities in astronautics. The committee, made up of the BIS, the Canadian Astronautical Society, the South African Interplanetary Society, and the Indian Astronautical Society, proposed the meeting, which will have as its central theme the question of Commonwealth participation in space research.

The meeting will consider such subjects as the form a Commonwealth space flight program should take; research activities which would be best served by a joint program (not conflicting with work already undertaken in the U.S. and U.S.S.R.); organization and administration problems; economic considerations; industrial and university participation; and assessment of facilities.

More Krypton 85 Available

In response to requests from industry, the AEC has increased the quota of krypton 85 for civilian uses to 100,000 curies per year. The Commission charges $50 for each of the first two curies and $15 for each additional curie.

Supersonic Ramjet

(CONTINUED FROM PAGE 48)

of the throat. (Conventional diffusers for subsonic flight are designed with angles of 6 to 7 deg for maximum pressure recovery, but in subsonic diffusers there is no normal shock wave which tends to separate the flow next to the walls.) These small angles require rather long ducts to bring the air back to the burner face; and if a very smooth flow profile is required, even added length and a contracted burner entrance may be desired.

Another factor which must not be overlooked in the layout of a compression field is the pressure-rise limitation through oblique shocks or isentropic compression. A condition must be met at the intersection of the shocks such that the pressure due to oblique compression is not as great as that due to a normal shock at free-stream Mach number. This limits the amount of supersonic turning that is available from a cone.

Likewise, the deflection angle of the cowl must not be so severe that it causes local shock detachment of the internal flow. That is, the local flow (behind the cone shocks) which approaches the cowl must be at a high enough Mach number to assure oblique shock wave attachment. From experience it has been found that the internal angle of the cowl lip should be about 5 deg less than that theoretically required for the local-flow shock detachment. This will account for boundary layer growth and other uncertainties in the mixed gradient field usually present. Also, the cowl angle must be carried aft for sufficient distance before further turning to prevent the buildup of a large pressure gradient and flow separation. The distance the internal cowl angle is maintained can best be determined from experience gained by testing wind tunnel models. The external drag of the resulting cowl shape is another factor to be considered.

Let's look now at some problems of stabilizing airflow into a diffuser. The definition of critical point is the maximum pressure recovery at constant capture area. Supercritical operation is at constant capture area but reduced pressure recovery. Subcritical operation is at reduced capture area.

Flow instability, referred to as "buzz" or, as in a compressor, "surge," is a pulsating flow which occurs when airflow is reduced. Unstable operation occurs at subcritical flow when the pressure recovery characteristic decreases with decreasing capture area ratio. There are a number of causes for "buzz." Most can be included in this general statement: As the airflow is reduced, the flow into the inlet is changed in such a way that greater losses in pressure recovery occur with more airflow reduction. One way this happens is: The large pressure gradients from the normal shock, which had occurred downstream of the inlet throat, are forced forward into the throat, causing separation in this critical area and creating greater pressure losses than before the airflow was reduced.

The system, which oscillates, can be compared to a mechanical system by considering the air volume in the burner as a spring and the column of air in the diffuser throat and duct to the burner as a mass to be set in motion. Air is expelled out the front of the inlet in the middle of the cycle, as can be seen in the series of photos on pages 46 and 47. In this oscillation, the airflow rate and the pressure levels fluctuate by a large amount, such that large mechanical vibrations are set up in the inlet structure. Such vibrations can cause the lightweight aircraft structure to fail from overload. Also, the effect on a ramjet burner is so violent that it may quit burning. Even if the burner stays lighted, the large drag increase for subcritical operation causes a loss in thrust. For all these reasons, the designer either makes the inlet stable or de-rates the ramjet so that it will never go subcritical.

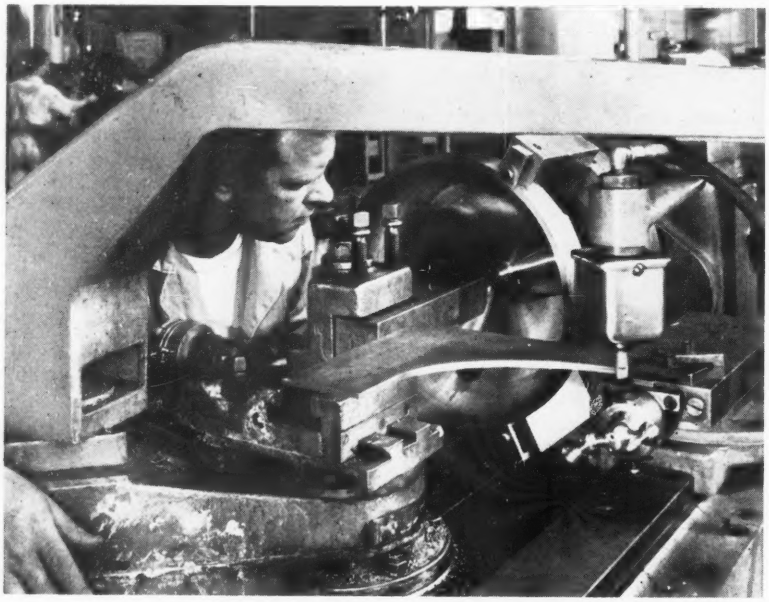
One way to add stability to an inlet at subcritical flow is to bleed the boundary layer from the surface of the inlet throat. By removing this low energy air, separation can be avoided and the stable subcritical range of the inlet can be increased. Similarly, if free-stream air is entering the inlet, the cone compression can be redesigned so that more air is deflected supercritically. Then when the inlet is operated subcritically, there is still oblique compression working on the air as flow is reduced.

Drag Penalty

Both of these methods produce stability at the expense of drag. However, in some inlet applications the assurance of stable operation compensates for drag penalty, and in some cases the increased pressure recovery due to bleed can more than compensate for the loss due to drag. Designing the shock pattern to pass in front of the cowl will create some "streamline drag" but this may be less in the over-all effect than de-rating the ramjet to avoid the subcritical operation.

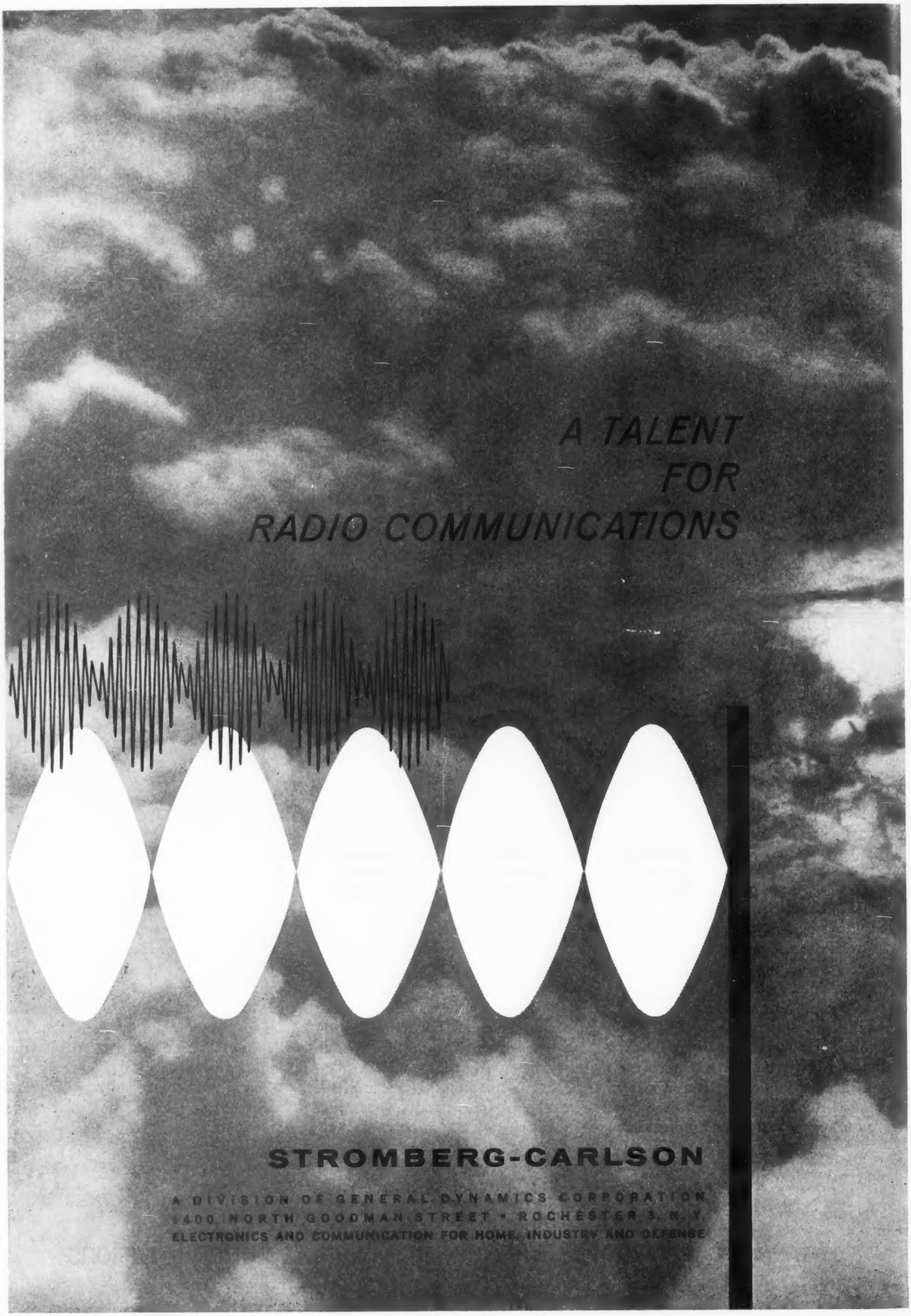
Another factor to be considered is the internal contraction of the inlet, i.e., the ratio of the cross-sectional area of flow at the cowl entrance to the flow cross-section at the throat.

(CONTINUED ON PAGE 71)



Precision Boring of Missile Bulkheads

A machinist at Diversey Engineering Co. counter-bores hi-nickel alloy forward bulkhead sections for ground-to-air missiles with an accuracy of +0.001 −0.000 in., by using carbide tooling on a Monarch 20-in. manufacturing lathe equipped with a swiveling air-gage tracer system.


A TALENT
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An inlet which has variable walls can use a much larger contraction, and thus get more supersonic pressure recovery than a fixed-wall inlet. The nearly isentropic compression theoretically available in a contracting channel cannot be realized in actual flow, because, in the process of accelerating the aircraft from subsonic to supersonic speed, a normal shock wave forms just above Mach 1.0.

This normal shock generates such large total pressure losses that at higher Mach numbers all the airflow has insufficient pressure to go through the throat designed for isentropic flow. The excess flow must be spilled around the inlet. The normal shock continues to stay out in front, generating great losses in total pressure and spilling the excess air around the inlet until the variable throat walls or bypass valves are opened to let all the flow go through.

When this happens, the normal shock flows downstream, and the more nearly isentropic shock pattern can be set up, i.e., flow has "started." Then the walls can be closed down again to a nearly isentropic setting with a much smaller throat, and high pressure recovery can be realized. This arrangement, however, is quite unstable and depends upon mechanically driven walls or doors to restore supercritical operation whenever the inlet inadvertently goes subcritical.

So, for a fixed wall inlet, the contraction ratio must be limited to that which will permit normal shock losses in the local flow-field and still pass all the airflow at the design speed. In practice, there are boundary layer losses as well, so that even the theoretical contraction for local normal shock criterion must be allowed about 5 to 10 per cent margin. That is, the throat should be made 5 to 10 per cent larger than theory would compute.

As in most aircraft and missile design problems, there are compromises which must be made in designing an optimum inlet. Since pressure recovery can in general be increased by increasing the cowl angle, the drag will also increase. Whether this increase in drag penalizes the vehicle more than the pressure recovery increase aids it, is a question that requires in the answer a number of ingredients in addition to merely the pressure recovery and drag.

If the vehicle has a high-thrust engine, such as Bomarc, then the important factor may be the acceleration of the missile or the surplus of thrust from the engine over the drag of the missile. The optimum balance between inlet pressure recovery and inlet drag will be different from that optimum for a long-range fixed-speed cruising missile, such as Navaho.

The graphs on page 48 summarize a typical cruise type inlet study. Using drag and pressure recovery from this figure, the missile range could be calculated for each of several cowl angles. In the range equation, the drag will influence the lift to drag ratio term, and will determine the thrust level for engine operation. At this thrust level the value of pressure recovery will determine the specific fuel consumption of the engine. The weight ratio in the equation will be influenced by pressure recovery through its effect on engine and duct weight. These are the primary affects. To get all the secondary effects into the analysis, complete design studies have to be made at each value of the parameter, cowl angle.

In the Navaho program, a scale model, shown on page 48, was built to measure the pressure recovery and drag. The test results are indicated by the accompanying graph on page 48. This type of model requires very accurate measurements to get credible drag results (because the sum of the forces on the inlet involves a number of large forces, the difference of which, external drag, is rather small). In the model pictured, the drag of the boundary layer bleed could be measured as well as the cowl and additive drag.

Getting An Accurate Value

A method for getting an accurate value for the internal momentum term is to use an exhaust nozzle which has an elliptical shape to provide a uniform Mach 1.0 exit stream. If this nozzle is designed as carefully as a transonic wind tunnel nozzle, then airflow and the exit momentum can be measured precisely, and the internal momentum term will be known with good accuracy.

These external drag results had a scatter of only ±6 per cent with the model. They were used in the Navaho design to determine the cowl angle and, thus, the balance between external drag of the inlet and pressure recovery for maximum range.

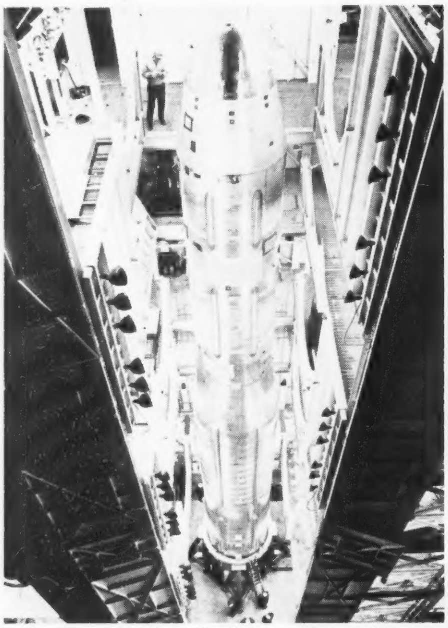
Suggested Additional Reading

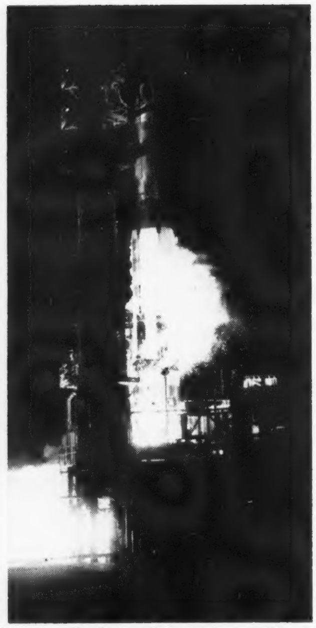
Ferri, A., *Elements of Aerodynamics of Supersonic Flows*, Macmillan Co., 1949, pp. 179–194.

Shapiro, Ascher H., *The Dynamics and Thermodynamics of Compressible Fluid Flow*, pp. 143–159 and 689–694.

How to Match Ramjet Inlets and Performance, A. N. Thomas, Aviation Age, February 1956.

Titan Flight-Tested





Left, Titan receives final inspection at Martin-Denver before shipment to Cape Canaveral. At right, Aerojet first-stage engine goes through static test in preparation for launching. Aerojet is developing both first- and second-stage engines for the AF ICBM.

During February, Titan made its first and second successful flight tests under propulsion of the first-stage engine from Cape Canaveral. The Air Force and Martin-Denver, principal contractor for the 9000 mile ICBM, announced that these tests begin flight evaluation of ground support equipment, launching and sequence controls and equipment, the missile safety system, and in-flight telemetry. Full-power tests will start soon.

Air-Turborocket

(CONTINUED FROM PAGE 37)

acceleration, one engine design would result. Another design would be required for a mission which featured a long cruise phase. On the other hand, while not optimum, a single engine design will bridge these two extremes to a remarkable degree of practicality, and therein lies the versatility of the monopropellant air-turborocket.

Engine Tested

After a period of preliminary design and bench-scale laboratory testing, a complete monopropellant air-turborocket engine was operated May 27, 1955, on a test stand at Experiment Incorporated. Subsequently, these tests were expanded to include a wide range of simulated flight conditions. During these tests, turbines were operated at temperatures on the order of 2400 F. This was possible because certain of the monopropellants have decomposition products of a completely reducing nature, thereby permitting the use of uncoated molybdenum or molybdenum-alloy construction.

The development of the air-turborocket engine was originally stimulated by consideration of applications in the relatively short range surface launched missile field. By initially operating at high fuel flows to obtain high specific thrusts and subsequently leaning down to a more economical cruise condition, a wide range of flight regimes can be encompassed with a single air-turborocket engine. Investigation of a number of applications where use of the air turborocket would be feasible have indicated that a marked saving in the takeoff weight and size would result without sacrifice of performance capability in terms of carrying a given payload to the required range and altitude.

Of special current interest is the possibility of using the air-turborocket as the first stage of large multirocket assemblies of the type used for launching sounding devices, ballistic missiles, satellites or other astronautical vehicles. The high thrust per unit cross section and per unit weight, together with the excellent specific impulse characteristic of the air turborocket, make it particularly adaptable for this purpose.

Consider the problem of the Vanguard satellite launcher. About 1000 lb of initial weight are required for each pound of payload delivered at its destination. Future requirements for both long-range weapons and space vehicles will involve much larger payloads. To launch such devices, if we continue to work on the 1000-to-1 basis, initial weights are involved which begin to be impractically large. While newer techniques in propellants and construction will improve this ratio, even larger gains appear to be possible through the use of an air-breathing first stage in lieu of the rocket.

The bottom figure on page 37 shows the result of one comparative study in which an air-turborocket engine was substituted for the rocket first stage in a Vanguard-type mission. It appears that the same end result can be achieved with only half of the initial takeoff weight. This comparison was based on current state of the art. With foreseeable improvements, it is possible that the initial weight could be cut by as much as a factor of 3.

With a weight-saving leverage of this magnitude, it is reasonable to consider a recoverable first stage, the heaviest and most expensive part of the vehicle. Such a first stage, unguided or even piloted, would serve as a "ferry" to carry the other stages to the edge of the atmosphere. Its duty completed, it would return to its base or be recovered in some other fashion. The top picture on page 37 illustrates this concept as applied to a manned space vehicle.

Offers Certain Improvements

It seems more logical to take advantage of the atmosphere through the employment of an air-breathing first stage than to fight against it, as is the case when a rocket is employed for this purpose. Within the atmosphere, the air-turborocket offers a two- to fourfold improvement in specific impulse even over what is anticipated in future rockets. Propulsion efficiencies also are more nearly optimized. On the other hand, at the altitude where the air breather begins to deteriorate, the rocket is just beginning to come into its own.

These factors taken together make the monopropellant air turborocket a powerplant of great potential usefulness in future astronautical programs, either for military or exploration purposes.

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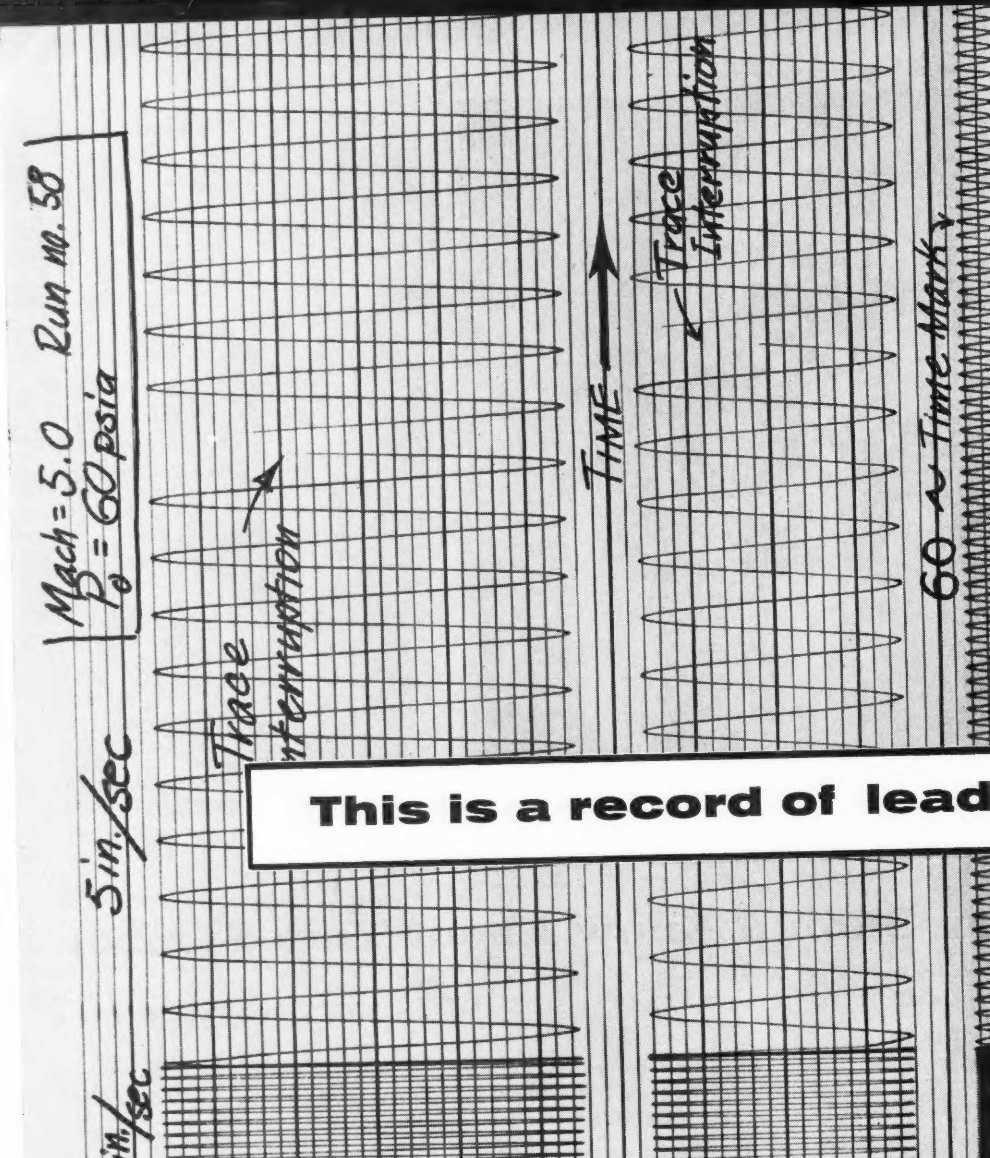

Honeywell 906A Visicorder record, actual size. Note longitudinal grid lines and trace identification interruptions.

This is a record of leadership in

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HONEYWELL

These studies of aerodynamic damping coefficients on an airframe were made by engineers at ARO, Inc. They were conducted in the Gas Dynamics Facility at the U.S.A.F.'s Arnold Engineering Development Center, Tullahoma, Tennessee, wind tunnel center of the Air Research and Development Command. The studies were directly recorded on a Honeywell 906-A Visicorder.

The problem: To measure damping-in-pitch derivatives for a clipped-delta-wing-body configuration over a Mach number range of 2.0 to 5.0 so that these measurements could be compared with the Mach number trend predicted by theory.

The set-up: A model of the delta-wing body, mounted on its cross-flexure pivot support, was forced to oscillate through a linkage by an electro-magnetic shaker. Resistance strain gauges were bonded to the input torque member and to one of the pivot supports. These gauges supplied torque and displacement signals through a carrier amplifier to two galvanometers in the Visicorder. An oscillator, driving a third galvanometer, established a time base for the oscillogram.

The values discovered through this forced-oscillation balance system experiment showed some discrepancies from values predicted by theory, because the theory pertained to simpler bodies than that used in the tests. The experiments provided a new set of data which will result in more accurate predictions for future design.

in aerodynamic research

Z. A. Woodard, Jr., ARO, Incorporated, instrument technician, operates the Visicorder in the measurement of aerodynamic damping coefficients.

The Honeywell Visicorder is the pioneer and unquestioned leader in the field of high-frequency, high-sensitivity direct recording oscillography. In research, development and product testing everywhere, instantly-readable Visicorder records are pointing the way to new advances in product design, rocketry, computing, control, nucleonics . . . in any field where high speed variables are under study.

The new Model 906A Visicorder, now available in 8- and 14-channel models, produces longitudinal grid lines simultaneously with the dynamic traces, time lines, and trace identification by means of new accessory units.

To record high frequency variables—and monitor them as they are recorded—use the Visicorder Oscillograph. Call your nearest Minneapolis-Honeywell Industrial Sales Office for a demonstration.

Reference Data: Write for Visicorder Bulletin
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Honeywell

HONEYWELL Industrial Products Group

Vanguard "Weather Eyes"

These two photocells, developed by Perkin-Elmer, are the eyes of Vanguard II, the world's first weather satellite.

Vanguard II, the $21\frac{1}{2}$-lb weather satellite launched Feb. 17, carries two $3\frac{1}{2}$-oz photocells that register the intensity of sunlight reflected from clouds, land, and sea, and convert this radiation to electrical signals, which are coded, stored on magnetic tape, and later broadcast to ground stations.

The photocells, developed and built by Perkin-Elmer for the Army Signal R&D Lab, which designed Vanguard II instrumentation, have a very fast ($f/0.7$) optical system based on a 3 in. diam mirror, an IR detector, and a solar battery-powered switch, all mounted in a stainless-steel cannister. The switch automatically turns off the instrument system when the satellite passes over the dark side of the earth.

The tape recorder and battery pack, developed by the Signal Labs, forms a cylinder $5\frac{1}{2}$ in. in diam and 3 in. high, which weighs $1\frac{1}{2}$ lb. This pack records at 0.3 ips, plays back at 15 ips (one minute allowed for playback), and was to operate two weeks on its battery power.

Soviet Astronautics

(CONTINUED FROM PAGE 32)

Society for Assistance to the Army, Air Force, and Navy), and corresponds to the American amateur radio magazine *QST* published by the American Radio Relay League. *Vestnik Vozdushnogo Flota* is one of the many military journals published monthly by the U.S.S.R. Ministry of Defense. Since November 1957, it has published several articles on space flight, and since June 1958, it has been featuring a series of detailed articles on rocket engines. *Vestnik Akademii Nauk SSSR*, a pan-scientific *Physics Today*, carries news of and feature articles on scientific developments in the U.S.S.R.

Because the Astronomical Council of the U.S.S.R. Academy of Sciences, through its permanent Interdepartmental Commission on Interplanetary Communications, is allegedly the agency responsible for the conduct of the Soviet space flight program (at least the scientific aspects thereof), it is logical to expect that certain phases of this program would come to light in the pages of the Academy's scientific journals.

This has indeed been the case. Even before Sputnik I was launched, a number of space flight research papers appeared in *Uspekhi Fizicheskikh Nauk* (Advances in the Physical Sciences), with some 17 articles appearing in the September 1957, issue alone; *Astronomicheskii Zhurnal* (Astronomical Journal); *Byulleten' Instituta Teoreticheskoi Astronomii* (Bulletin of the Institute of Theoretical Astronomy); *Doklady Akademii Nauk SSSR* (Reports of U.S.S.R. Academy of Sciences), which published papers limited to four-page summaries of original research in all fields; *Izvestiya Akademii Nauk SSSR, Otdelenie Tekhnicheskikh Nauk* (Proceedings of the U.S.S.R. Academy of Sciences, Division of Technical Sciences); *Izvestiya Akademii Nauk SSSR, Seriya Geofizicheskaya* (Proceedings of the U.S.S.R. Academy of Sciences, Geophysical Series); *Prikladnaya Matematikai Mekhanika* (Applied Mathematics and Mechanics); and other journals.

Since the Sputniks, the U.S.S.R. Academy of Sciences has been publishing the results of its theoretical and experimental space flight research not only in its established scientific periodicals, but also in special collections, such as the one entitled *Preliminary Results of Scientific Researches on the First Soviet Artificial Earth Satellites and Rockets*, dated July 1958.

Technical papers of considerable merit on astronautical subjects are also found in journals published by various agencies independent of the U.S.S.R. Academy of Sciences. Some of these—including the popular science periodicals mentioned earlier—are listed in the table on page 31. The publications of universities and technical institutes are fruitful sources of information. By consulting the Library of Congress' *Monthly Index of Russian Accessions*, and scanning the translated tables of contents of periodicals listed therein, the reader can determine which publications carry articles pertaining to the broad field of astronautics.

Articles from a large number of technical and nontechnical Russian journals are indexed by author and subject in the bibliographic bulletin *Letopis' Zhurnal'nykh Statei* (Chronicle of Journal Articles), published weekly by the All-Union Book Chamber. It is interesting to note that articles on astronautics are indexed under the subject category "Transport," subcategory "Cosmonautics," whereas those in contributory fields are indexed under appropriate categories and subcategories. Abstracts of articles on astronautics from the worldwide literature are found in the monthly periodical *Referativnyi Zhurnal: Astronomiya i Geodeziya* under the category "Mezhplanetnye Soobshcheniya" (Interplanetary Communications). Other pertinent abstract journals are listed in the table on page 32.

The lists of newspapers and journals presented in these tables are not intended to be exhaustive. They are, for the most part, representative of the so-called central, or national, newspapers and journals. Besides these, there are many regional, or union republic, newspapers and periodicals that contain material not necessarily found in the national dailies and periodicals. The task of monitoring the entire output of Soviet periodical literature—in the sphere of astronautics alone—would be Herculean. Even the bibliographic bulletins *Letopis' Gazetnykh Statei* and *Letopis' Zhurnal'nykh Statei* do not accomplish this feat.

Because Western scientists and engineers have shown a tremendous interest in the scientific and technological advances of the Soviets, much of their technical literature is being translated into English. Information concerning translations of Russian technical articles may be obtained by writing to Miss Lillian A. Hamrick, Chief, Technical Information Div., Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C. Many articles that were published in the newspapers and journals listed in the tables have appeared in translation in *Soviet Bloc International Geophysical Year Information*, published weekly from February 14, 1958, to January 2, 1959, by the U.S. Department of Commerce, Office of Technical Services, Washington 25, D.C., as an aid to U.S. government research.

Small Rockets Jockey Vanguard

Four Atlantic Research 0.6-lb. solid rockets, each delivering a 50-lb impulse in 1 sec, help separate the third stage of Vanguard and stabilize it. Two, used as retrorockets, slow the second stage to effect clean separation, and two spin-stabilize the unguided third stage.

People in the news

APPOINTMENTS

Howard S. Seifert, ARS national vice-president, has been appointed special assistant for professional development, Space Technology Labs.

Howard A. Wilcox has been appointed DOD deputy director of defense research and engineering to Dr. Herbert York. Dr. Wilcox was formerly head of the Rocket Development Dept. and then assistant technical director for R&D at NOTS, China Lake, Calif.

Thompson Ramo Wooldridge Inc. has elected four new vice-presidents at its Thompson Products Divs. in Cleveland. New officers are **Pierce T. Angell,** engineering manager of the Tapco Group; **Robert E. Cummings,** manager of the Thompson Products Valve Div.; **William M. Jones,** manager of the Thompson Products Commercial Electronics Group; and **Carl L. Kahlert,** manager of the Thompson Products Replacement Div.

Former WADC Chief **Maj. Gen. Frederick R. Dent Jr.** (AF-Ret.) will head The Martin Co. Baltimore Div.'s new Missiles and Electronic Engineering Div. and **Herman Pusin,** former chief engineer, the new Manned Vehicles Engineering Div., replacing the previous single engineering division. **George D. Sands,** former chief of the Nuclear Branch, Army Transportation Research and Engineering Command, joins Martin as director of scientific requirements, while **Clare P. Stanford** becomes chief of the Nuclear Div.'s Engineering Dept., succeeding **J. A. Hunter,** who has been assigned to the office of Martin's vice-president for engineering.

Lyman C. Joseph III, project engineer for the F8U-1 Crusader, Chance Vought, has been promoted to chief engineer-aircraft. In a realignment of the Engineering Dept., the following new assignments were made: In advanced weapons: **C. A. Lau,** chief of advanced aircraft; **L. B. Richardson,** project engineer, advanced aircraft; **H. M. Graham,** weapons system project engineer for aircraft; **Whitney McCormack,** aircraft design group; **L. R. Smith,** senior specialist, aircraft technical group; **W. C. Boyce,** aircraft design group; **R. S. Stewart,** chief of advanced missiles; **L. J. Boyer,** senior specialist, advanced weapons systems planning group; **G. C. Robinson,** senior specialist, advanced weapons systems planning group.

In missile engineering: **J. W. Ludwig,** chief project engineer, Army missiles; **R. T. Hill,** senior specialist, Army missiles project; **Milton Green,** responsibility for directing activities of Regulus project group; **A. F. Roberts,** missile test and evaluation section.

In aircraft engineering: **J. E. Gathings,** senior engineer, propulsion; **R. B. Eberle,** senior specialist, aerodynamics; **F. T. Gardner,** senior engineer, aerodynamics; **T. R. Salter,** senior specialist, aerodynamics; **J. H. Best,** structures project engineer, B-70; **A. L. Lang,** senior specialist, structures; **B. D. Brandon,** responsibility for directing activities of equipment and cockpit design group.

In electronics engineering: **Prentiss Selby,** senior specialist, electronics research and development group.

S. O. Perry, former chief engineer of missiles, becomes director of the newly formed Range Systems Div.

John P. Butterfield, former executive engineer of Chrysler's Missile Div. has been made director of the Defense Group's newly formed advanced projects organization, while **G. W. Trichel,** president, Amplex Div., has been named military adviser to T. F. Morrow, group vice-president of defense and special products.

Robert E. Williams has been upped from project manager, Airborne Electronics Dept., Stavid Engineering, Inc., to manager of the department.

Edward W. Schening has been appointed general manager of the newly established Military Electronic Computer Div. of Burroughs Corp. He was formerly manager of the Burroughs defense plant.

Chris G. Fahy has been promoted to director of quality assurance at McCormick Selph Associates.

O. G. Haywood has been appointed corporate group vice-president for military products and industrial instruments for F. C. Huyck & Sons. Haywood was formerly vice-president of Emerson Electric Mfg. Co.

Russell M. Ewbank has been named production manager of Narmco Industries Mfg. Div., while **W. S. Saville** has been appointed vice-president and technical assistant to the president.

Ralph W. Waniek, has been appointed director of research of the new Magnetohydrodynamics Lab at Giannini Plasmadyne Corp.

George J. Brown, has been advanced from project engineer to chief engineer of Statham Instruments, Inc.

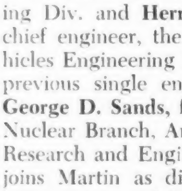
Norman H. Holt, former electronic production engineering section chief, has been named reliability coordinator for the Aeronautical Div. of Minneapolis-Honeywell Regulator Co.

George P. Sutton, Hunsaker professor of Aeronautical Engineering at MIT and immediate past president of ARS, has been appointed chief scientist of ARPA.

Following appointments were made at Linde Co. Div. of Union Carbide Corp.: **C. T. Fallon Jr.** to manager of cryogenic engineering, Los Angeles; **R. D. Gillis** to cryogenic engineer, Los Angeles; and **L. N. Johnson,** cryogenic specialist, San Francisco.

Harrison F. Edwards, former technical operations manager, Contracts and Service Div. of Simmonds Aerocessories, Inc., has been appointed to chief engineer, product engineering, Manufacturing Div.

W. A. Pulver, has been upped from chief engineer to assistant general manager of Lockheed Aircraft's Georgia Div.; **Arthur E. Flock,** chief advanced systems research engineer, Calif. Div., succeeds Pulver. **Carl E. Johnson,** former vice-president, engineering, for Scaife Co., joins Lockheed's Missiles and Space Div. as ex-



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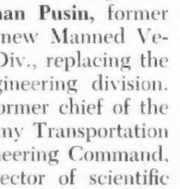

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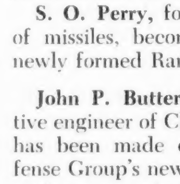

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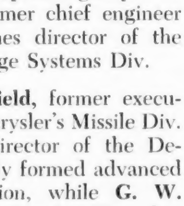
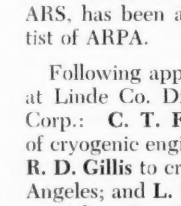
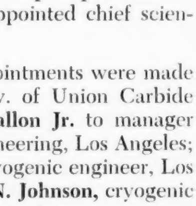


Trichel



Williams



Fahy

STEPS IN THE RACE TO OUTER SPACE

Lunar Unicycle

This 30-foot high Unicycle is designed for preliminary exploration of the Moon, once a base camp has been established. It's entirely constructed of inflated, rubberized fabric, with the exception of strengthening members, hatches and a few other items of equipment. Gyros stabilize and steer the vehicle; electric motors furnish the driving power.

Electricity for the motors and instrumentation comes from solar batteries mounted in the "parasol". The cleated, rotating wheel upon which the Unicycle travels is made of inflated tubes. A spare wheel, carried around the body, acts as a bumper in traversing narrow defiles. Built in two sections, these wheels are assembled by belt-lacing type fasteners.

The upper level, the navigating and communications deck, is ringed with recording and surveying instruments. Living quarters make up a middle deck and below is the hold with supplies, spacesuits, oxygen equipment and spare apparatus, needed for survival.

In the background, two of the expedition's ferry ships are seen; one landing, one unloading in the bright Earthlight.

Inertial navigation systems will play an increasing role in the exploration of outer space. ***ARMA***, now providing such systems for the Air Force ATLAS and TITAN ICBM's, will be in the vanguard of the race to outer space. ***ARMA*** . . Garden City, New York. A Division of American Bosch Arma Corporation.

AMERICAN BOSCH ARMA CORPORATION


Mason


Orr


Elzufon


Burrows


Roberts


Adamson

ecutive assistant to Willis M. Hawkins, assistant general manager.

Calvin A. Gongwer, named head of Aerojet-General's Systems and Underwater Engine Divs., will manage the company's new Anti-Submarine Warfare Div. **Howard P. Mason,** former executive assistant in Aerojet's Missile Range Div., has been named corporate base manager for the Pacific Missile Range. **Ephraim M. Howard** has been promoted to head of the Systems Integration Dept. Minuteman Engineering Div. at the company's solid rocket plant. Formerly, he was a technical specialist on special assignment to the manager of Applied Mechanics and Systems Div. and headed Fluid Mechanics and Heat Transfer in the Aerophysics Dept.

Kenneth F. Miller becomes director of the new Military Electronics Dept. at Beckman Systems Div.

John W. Tukey, professor of mathematics at Princeton Univ. and a member of the Mathematical Research Dept. of Bell Telephone Labs., has been appointed assistant director of research in communications principles at the Labs.

David V. Orr has been appointed chief engineer at B&H Instrument Co., Inc.

Alexander F. Giacco, former senior technical specialist in Hercules Powder Co.'s Explosive Dept. Chemical Propulsion Div., has been named manager of plans and programs for the division. **M. Clayton Burgy,** former assistant manager of the Hercules explosives plant, Ishpeming, Mich., becomes technical specialist at the company's new rocket propellant plant at Bacchus, Utah. **Clement J. Koeferl,** Dynamite Dept. supervisor at the Carthage, Mo., explosive plant will succeed Burgy.

George Juris Purins joins the Chemical Engineering Group at Atlantic Research Corp., where he will work on the development of high energy propellants for rockets and other devices. **Eugene E. Elzufon** has been appointed director of research for AR's subsidiary, U.S. Flare Corp., where he was a staff engineer of the development office.

Carlos C. Wood, becomes director of advanced engineering planning, a newly created post at Douglas Aircraft. He formerly was chief engineer at the Long Beach Div., and will be succeeded in that post by **Charles S. Glasgow,** former assistant chief engineer.

William D. Tasker, becomes manager of the Hustler program office for Special Tube Operations, Sylvania Electric Products, Inc.

Robert T. Harding has been appointed assistant chief engineer, Product Design Dept., Arma Div. of American Bosch Arma.

David J. Craig has joined Wyandotte Chemicals' Research Div. as supervisor of liquid propellant development in the Contract Research Dept.

Archie G. Buyers has been named to a research position in the Space Technology Div. of Aeronutronic Systems, Inc.

R. L. McCreary will head the new R&D Div. C at Collins Radio Co.'s Central Div., while **E. H. Fritze** will head Div. D, both formed to support expanded activities in basic research and flight control programs.

Charles R. Burrows, former vice-president, engineering, Ford Instrument Co. Div. of Sperry Rand, has joined Radiation Inc. as vice-president and director of engineering. **George S. Shaw,** vice-president and director of engineering becomes staff vice-president.

Richard E. Roberts of GE's Missile and Space Vehicle Dept., has been named to head the newly established instrumentation and communications organization for missiles and space vehicles. **Arthur P. Adamson,** former manager of the Flight Propulsion Lab Dept.'s Engine Development operation, has been appointed manager of the company's new vertical takeoff and landing engine development project.

John A. Dickie, has been elected president of the newly formed Unholtz-Dickie Corp., which will handle engineering services on vibration problems. **Karl Unholtz** has been named vice-president and chief engineering officer.

Robert M. Hayflick has joined Kearfott Co., Inc., as manager of the preliminary design section.

HONORS

William H. Pickering and **James A. Van Allen** have received the Army's Distinguished Civilian Service Award. Dr. Pickering, JPL director, was cited for exceptional technological and leadership contributions to the Army's mission in the intermediate range missile and space fields; Dr. Van Allen, chairman of the Univ. of Iowa Dept. of Physics, for his exceptional contributions in the conception, planning, and execution of the scientific research phase of the U.S. IGY Program.

DEATHS

Norton B. Moore, first president of the St. Louis section of ARS, died Dec. 11, 1958 in Santa Barbara, Calif. Dr. Moore was born in Oakland Calif. in 1909. After receiving a Ph.D. in aeronautical engineering, magna cum laude, from CalTech in 1934, he taught at the Univ. of California and then, for some 15 years beginning in 1942, he headed missile engineering and research groups for such companies as Curtiss-Wright, Aerojet, McDonnell Aircraft, and Aerophysics Development Corp. He recently headed his own consulting firm.

John P. Toner, assistant chief engineer and head of the Research Dept. at Arma Div., American Bosch Arma Corp., died last Dec. 25 at the age of 46, at his home in Halesite, N.Y.

Charles S. Redding, 75, chairman of the board of directors and former president of Leeds & Northrop Co., died on Jan. 2.

Truax to Leave Navy

Capt. Robert C. Truax, past president of ARS, currently with ARPA, has requested retirement from the Navy effective June 1, at which time he will have completed 20 years of service. He plans to enter private industry.

"COMPUTER PROGRAMMING *at SDC is a fundamental discipline rather than a service. This approach to programming reflects the special nature of SDC's work—developing large-scale computer-centered systems.*

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NO MONDAY

MORNING

QUARTERBACK

Hypersonic Aerodynamics

(CONTINUED FROM PAGE 35)

sure is small compared with pressures in the flow-field behind the shock, and consequently free-stream pressure may be neglected. Also the free-stream enthalpy is small compared with the specific kinetic energy of the flow, and may be neglected. With this general concept, the flow-field becomes independent of Mach number in all respects, and the principle applies to all viscous and rarefied gas effects as well as to an inviscid flow-field.

A second general principle applies to slender pointed bodies in hypersonic flow, with the thickness ratio (τ) (and angle of attack) of the body small and with M_∞ large. Under these conditions the local Mach number is everywhere large, and the inclination angles of shock waves and Mach waves to the free-stream direction are everywhere small. The motion of individual air particles in a system of coordinates fixed in the undistributed gas is almost in transverse planes, with but very little motion in the axial direction. With the axial motion of the particles neglected, a thin slab of fluid lying between two transverse planes, as indicated in the drawing on page 34, behaves as though its motion were an unsteady two-dimensional motion constrained between the two transverse planes.

Thus the three-dimensional steady (unsteady in some cases) flow is equivalent to a two-dimensional unsteady flow in each slab. This equivalence principle was found by the author, and apparently independently by A. A. Il'yushin. In the Russian literature the equivalence principle is termed the law of plane sections. The equivalence principle underlies hypersonic similitude.

A third general principle available for flat slender bodies, such as a thin wing, is referred to as strip theory. For strip theory to be valid, the quantity τ/AR must be small, and the quantity $M_\infty AR$ must be large, where AR is a suitably defined aspect ratio for the body. Under these conditions the motion of individual air particles is almost in a plane perpendicular to the spanwise axis. With the lateral motion of the particles neglected, a thin slab of fluid lying between two planes perpendicular to the spanwise axis, as shown in the drawing on page 35, behaves as though its motion were a two-dimensional one constrained between the planes. Strip theory also applies to supersonic flow.

If both the equivalence principle and strip theory are valid, the flow in a cylindrical tube of fluid with axis perpendicular to both the free-stream direction and the spanwise axis acts as a one-dimensional unsteady flow with a piston at one end following a prescribed motion. An approximate theory for unsteady hypersonic flow based on this concept is known as piston theory.

We have not yet considered viscous effects, which govern heat transfer and skin friction, in this discussion of hypersonic aerodynamic theory.

Except at extremely low air densities, the transfer of shear stresses and heat to a body in a hypersonic flow occurs through a boundary layer. Although the underlying boundary layer concepts are no different in hypersonic than they are in supersonic flow, hypersonic boundary layers do have some characteristic features.

Total Heat Transfer

One such feature arises not from the flow being hypersonic, but from the fact that very high temperatures are generally associated with such flows; as in the inviscid part of the flow-field, dissociation may be important, with its consequent lowering of temperatures and temperature gradients. The direct heat transfer through the medium is also decreased, but this decrease is balanced by an energy transfer through diffusion of dissociated atoms. The total heat transfer is governed more by the enthalpy gradients (which are not decreased by dissociation) than by the temperature gradients. This general conclusion holds for both laminar and turbulent boundary layers.

Two features which are truly characteristic of hypersonic flow appear in the boundary layer of slender bodies. One of these appears if the leading edge is blunted. Even slight blunting creates a disturbance which is felt far downstream from the leading edge; a region of high entropy is formed near the body, and in this layer the flow is highly rotational. The boundary layer grows in a region of high vorticity, and this fact can strongly affect the manner in which the boundary layer grows.

The other characteristic feature appears when the boundary layer is laminar and the local Mach number just outside the boundary layer is high, with the external flow itself hypersonic. This will be the case on a slender body if it is sharply pointed, that is, if any blunting of the leading edge may be considered negligible. Then the temperatures through most of the boundary layer are very much higher than those outside the bound-

ary layer, and the densities are correspondingly much lower than those outside, as indicated in the figure on page 35. With the external Mach number sufficiently large, this fact holds even if the body is highly cooled and the body temperature is of the same order of magnitude or lower than the temperature outside the boundary layer. The consequence of this phenomenon is that the mass flow in the boundary layer is very small, and the displacement thickness of the boundary layer is but slightly less than the total thickness. The hypersonic boundary layer may be characterized as a relatively thick layer of very hot low-density flow.

If the Reynolds number is very high, corresponding to flight at relatively low altitudes, the boundary layer may be turbulent. If with a turbulent layer the body surface is insulated, the boundary layer should have high temperatures and low densities, and thus should have a relatively large displacement thickness just as in the laminar case. If the body surface is highly cooled, the situation is less clear, but it is likely that the high turbulent heat-transfer rates will result in a cooling of the entire boundary layer. We may expect that the influence of wall cooling may be more significant for the turbulent layer than for the laminar layer in increasing the densities in the layer and decreasing the displacement thickness.

Boundary layer interaction phenomena are very important in hypersonic flow. We may distinguish two major types of interaction. In one of these, the displacement thickness of the boundary layer, which is equivalent to a change in the shape of the body, influences the external inviscid field and the pressure distribution in it. This change in pressure distribution in turn affects the development of the boundary layer and its displacement thickness distribution.

In the other major type of interaction there is a flange, step, or incident shock which in the absence of the boundary layer would cause a rapid rise in pressure. The influence of this pressure rise is transmitted forward within the boundary layer, and affects the inviscid flow-field forward of the flange, step, or incident shock. The sensitiveness of the hypersonic boundary layer to interaction phenomena is due primarily to the extremely low densities within the boundary layer. These low densities not only make the boundary layer thick but make it susceptible to being strongly affected by pressure gradients.

The pressure interaction mentioned first can be very important in flight at very high altitudes. It has the feature that it is subject to important modification from three-dimensional effects, as a result of the susceptibility of the boundary layer to lateral pressure gradients. A requirement for three-dimensional effects to be negligible in determining the induced pressures from this interaction on a wing is that the aspect ratio Æ be very large. Since this is not apt to be the case for the wing of a hypersonic vehicle, we must conclude that generally three-dimensional boundary layer interaction effects are important whenever the pressure type of boundary layer interaction is important.

The effect of high wall cooling is quite marked. Although with high wall cooling the densities in a laminar boundary layer are still much less than in the exterior flow, the effect of high cooling is to cut down the displacement thickness from the insulated case by about 70 per cent. In addition, three-dimensional effects are strongly reduced, and interactions of the upstream-influence type (the second major type mentioned) are reduced.

If the boundary layer is turbulent instead of laminar, the picture is somewhat different. A turbulent hypersonic boundary layer is supersonic except in an extremely thin layer nearest the wall, and has far less susceptibility to upstream influence of a pressure gradient than does a laminar boundary layer. With a turbulent boundary layer, we may also expect that three-dimensional effects be less than with a corresponding laminar layer.

We next ask, what is the nature of aerodynamic forces exerted on a body in hypersonic flow? Outside the rarefied flow regime, transverse forces, and moments, such as the lift or rolling moment, are determined primarily by the pressure distribution, with the effect of shear stresses small. Here the main effect of viscous phenomena is through boundary layer interaction.

Drag may be considered composed of three terms, one from pressure distribution, one from shear distribution, and one from the drag of a blunted leading edge. It is convenient to separate conceptually the drag from the very high pressures on the tip of a slightly blunted leading edge as a term distinct from the pressure drag. In the pressure drag itself, we must recognize that the pressure distribution may be influenced both by boundary layer interaction and by the perturbation to the flow-field induced by a blunted leading edge.

In order to calculate the pressures on the body a solution is needed for a three-dimensional, nonhomentropic, highly rotational flow-field. In order to bypass this rather difficult and lengthy calculation where strip theory is valid, various approximate ways of estimating the pressure in two-dimensional flow are used. One of these, the shock-expansion method, is based upon a rational theory and can be considered as the lowest-order approximation in a successive approximation scheme. Its main disadvantage is that it is not accurate if the body is highly curved near its leading edge.

Two other methods of estimating the pressure in two-dimensional flow are the tangent-wedge method and the Newtonian pressure law. According to the first method, the pressure on a body is approximated as the pressure on a wedge with inclination angle equal to the local inclination angle of the body. According to the second, the pressure coefficient is simply 2 $\sin^2\sigma$, where σ is the local inclination angle, with perhaps a modification to make the formula give correct stagnation pressures at $\sigma = 90$ deg.

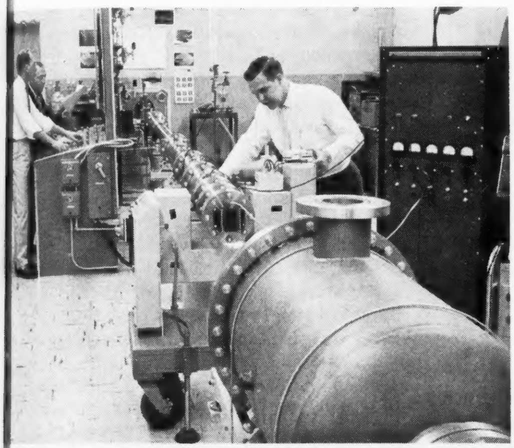
Basic Weakness

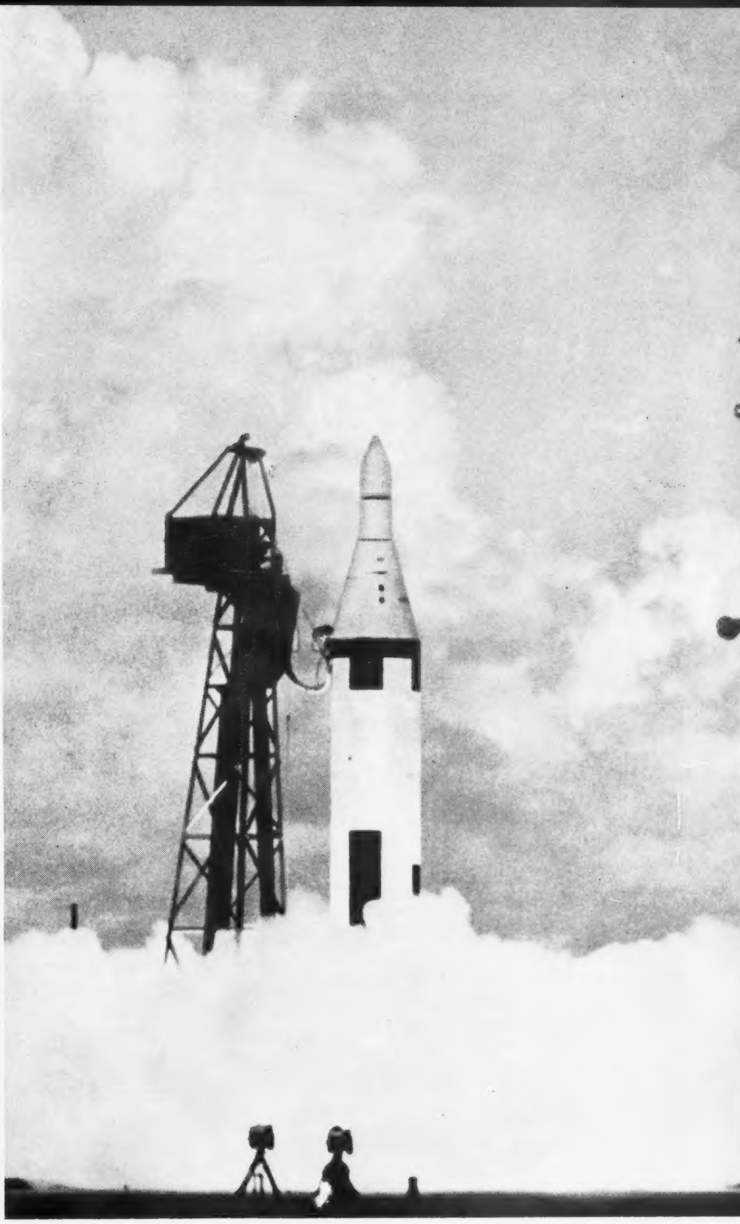
The basic weakness of both these methods is that for a curved body they have absolutely no basis in rational theory, and thus rest completely upon an empirical foundation. However, these methods both give results for the pressure which are of the correct order of magnitude, and they are very easy to apply. The tangent-wedge method is better for small incidence angles, and cannot be applied beyond the shock detachment angle. The Newtonian pressure law is better for large angles, and at finite values of M_∞ becomes incorrect for small angles. As is true for any empirical formula, these methods can not be trusted for shapes of any type for which experimental checks are not available. In particular, they can not be trusted to give good values for pressure gradients.

In linearized supersonic flow, with the pressure proportional to the angle

Rocket Abstracts Offered

A new monthly service, called "Rocket Reviews," is being offered by American Rocket Co., Box 1112, Wyandotte, Mich. The service will provide approximately 2000 abstracts yearly of technical articles and papers dealing with rocketry, guided missiles, and astronautics, taken from a large number of journals, as well as from meetings of many societies, in these fields. Price of the service is $120 per year.





of incidence on a thin symmetric wing, the additional drag due to lift is proportional to the square of the lift, or $\delta C_D \propto C_L^2$. In hypersonic flow, at sufficiently large incidence, the pressure is roughly proportional to the square of the angle of incidence. This leads to a formula of the form: $\delta C_D \propto C_L^{3/2}$. This alteration of the nature of the drag polar is but one example of the manner in which the nonlinear pressure dependence characteristic of hypersonic flow affects the aerodynamic force coefficients.

Suggested Additional Reading

H. J. Allen, *Hypersonic Flight and the Re-entry Problem* (Twenty-first Wright Brothers Lecture), J. Aero. Sci., Vol 25, pp. 217–229, 262 (1958).

W. D. Hayes and R. F. Probstein, *Hypersonic Flow Theory*, Academic Press, 1959.

Ramjet Fuel-Air Control

(CONTINUED FROM PAGE 43)

lated or trimmed as a function of closed loop control.

Since air spillage and buzz occur if the normal shock, which defines the region of transition from supersonic to subsonic flow, is expelled from the inlet, the fuel-air schedule has to be trimmed to create just enough blockage to move the shock to a maximum upstream position, just short of expulsion. The most direct means of determining shock location is to determine the static-pressure rise which occurs across it in the direction of flow. One or more total- and static-pressure taps of various configurations within the inlet will inform the fuel-air trim system of the shock location. Should the shock be too far downstream with respect to a particular tap, then the supersonic flow will result in a low static pressure, and a richer mixture will be required. The opposite is true if the shock is upstream of the desired location. Either proportional or integral control can be used for the trimming action, the choice depending on the required accuracy of maintaining a fixed pressure-recovery margin and on the nature of the inlet signals available. The proportional system can be implemented if the inlet signal gain is approximately constant, so that control stability and accuracy remain substantially the same for all flight conditions.

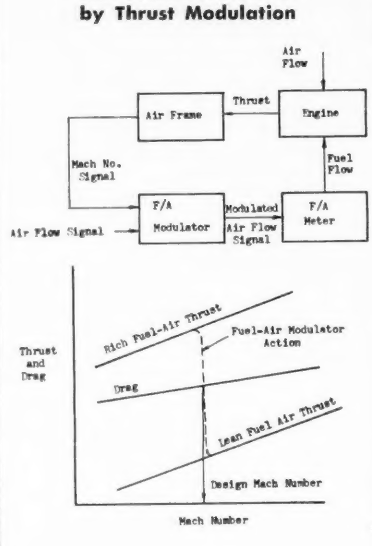
As in any other closed loop control, the optimum design represents a compromise between steadystate accuracy, dynamic stability, transient response, and the degree of hardware complexity. The predominant dynamic component in the loop is the ramjet itself. The transfer function can be calculated; or, better yet, it can be determined experimentally by introducing sinusoidal or step variations in fuel flow.

In general, ramjets exhibit a dynamic characteristic which can be described by one leading and two lagging time constants in combination with time delay. The period during which the output is not affected by an input disturbance is defined as time delay. The time subsequently required to reach about 63 per cent of the total output change is known as the time constant, provided the system is analogous to a simple spring-mass-viscous-friction device.

For a particular engine configuration, variations in Mach number, fuel-air mixture, and angle of attack influence the values of the lead and lag time constants. The time delay is primarily a function of pressure tap location; the further upstream the tap, the greater the delay will be. Although the control design strives for high loop gain and fast response to minimize steadystate errors and follow trajectory maneuvers, upper limits have to be imposed on gain and response to achieve a stable closed loop system.

For maximum powerplant efficiency, fuel-air trimming by closing the loop through the engine is mandatory. However, the price for the improved performance is increased complexity.

Mach Number Control by Thrust Modulation



For certain ramjet applications, the engine must modulate thrust to maintain a particular Mach number. Thus, upon approaching the vicinity of design Mach number, the acceleration schedule is leaned out until thrust equals drag, as shown in the figure on this page. In this case, the basic fuel-air schedule is closed through the airframe instead of the engine.

Mach Number Intelligence

Mach number intelligence can be obtained from one of a number of pressure ratios, as for example, free-stream impact pressure/free-stream static pressure. In general, the more sensitive the ratio is with respect to Mach number, the lower is the minimum pressure level which has to be utilized. Therefore, the primary choice of signals depends upon sensing ability and insensitivity to extraneous effects due to changes in angle of attack and yaw.

Since airframe dynamics in terms of a Mach number–thrust transfer characteristic are quite slow, relatively high loop gains and accuracies can be achieved in a proportional system. The requirement of operating a ramjet at de-rated power to control cruise Mach number naturally results in decreased efficiency, since less thrust is being delivered per pound of engine weight. A more efficient way of accomplishing the same result, mission permitting, would be variation of airframe drag by changing altitude.

Besides fuel-air modulation for the sake of optimum performance or Mach number control, burner pressure limits, combustion chamber temperature limits, or thrust balancing of a dual engine installation might also require the altering of the basic fuel-air calibration. Also, it must be pointed out that the components involved have to handle fuels varying up to 500 to 600 F in temperature in a single application. Finally, special design techniques are required to maintain the basic fuel-air metering schedule within narrow tolerance limits.

The design and development of ramjet controls and accessories represent a substantial percentage of the effort required to make the engine into a reliable and efficient propulsion device. This effort is well worth the while, since the success of a mission depends to a considerable extent on the ability of the control to merge inlet, combustion chamber, and nozzle into an optimum powerplant, one capable of delivering the required amount of thrust under all expected flight conditions.

Ramjet Combustion

(CONTINUED FROM PAGE 45)

phasized the extreme variance of ramjet combustors. Although the many types and wide range of operating conditions of the combustors are barriers to a simple straightforward discussion, it is possible to systematize the ramjet combustors by treating the discrete steps in combustion, common to all. All ramjet combustors involve the following processes: (1) *Fuel-air mixture preparation*—injection and fuel-air mixing (liquid fuels also involve atomization and vaporization); (2) *combustion*—ignition, flame stabilization, and flame spreading; and (3) *terminal processes*—control of outlet temperature profile, development of combustion gas homogeneity, and nozzle expansion.

Efficient utilization of the fuel requires precise control of fuel-air mixtures. At low Mach numbers, the over-all fuel-air ratios are often less than stoichiometric, so that the engine operates at a favorable propulsive efficiency level (low jet-flight velocity ratio). But the fuel-air ratios in the combustion zone must be near stoichiometric to attain maximum flame stability and efficiency. This is achieved by compartmenting the combustion process. At high Mach numbers over-all fuel-air ratios near stoichiometric are usually desired. Precise control is then needed to avoid wasting fuel in excessively fuel-rich zones.

The prerequisite of fuel-air mixture preparation and control is predictable airflow. Early ramjets were prone to produce highly distorted inlet flows, which varied with flight speed and flight attitude. Distorted airflows have been eliminated through aerodynamic redesign of the subsonic diffusion process.

Fuel jet penetration, atomization, evaporation, and mixing, which are the steps leading to controlled fuel-air mixtures, have been thoroughly explored analytically and experimentally. Simple fuel nozzles are often used in ramjets because the inlet-air velocity is high enough to furnish the energy required for atomization. Variable area or multiport injectors are used to reduce flow variations among injectors, rather than to provide better atomization. Since simple fuel injectors are used, simple analytical and empirical relations based on momentum of the jet and physical properties of the fuel and air stream may be used to describe the initial patterns of fuel introduction. Vapor fuels also use simple fuel injectors and respond to similar analytical treatment.

Atomization of fuel sprays is initi-

ated near the source of injection. Equations based on the balance between surface tension and dynamic forces of the air are used to predict drop-size distribution of fuel sprays.

Knowledge of the drop sizes permits the determination of vaporization rates. A great wealth of literature on single-drop vaporization rates exists and can be applied to full sprays, but the method is tedious. Steps involved are (1) calculation of drop-size distribution, (2) calculation of velocity of drops relative to the airstream (initially based on injector characteristics), (3) estimation of evaporation rate, (4) calculation of coefficient of drag of drop (Stokes law modified by evaporation rate), and (5) determination of new relative velocity. Since the steps are interrelated, an accurate numerical analysis for the entire droplet-size range requires a prohibitively large number of calculations. Usually, empirical relations of gross evaporation rates of typical sprays are used in combustor work. The more detailed single-drop treatments serve as useful guide lines in extrapolation to new conditions.

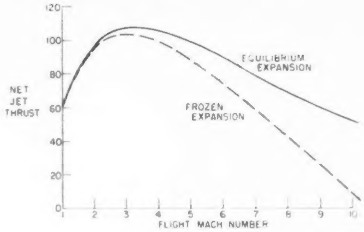
The degree of sophistication used in predicting liquid and vapor fuel-mixing rates varies from the "prior art" treatment to involved applications of statistical turbulent-transport theory. In all cases, mixing is assumed to start from a particular fuel source. The source is defined by the information on jet penetration and atomization.

Fuel-air mixing theory based on turbulent transport theory can be used to give a fairly graphic picture of the mixing processes. The airstream is described in terms of turbulent eddies of various sizes and local velocities. The velocity fluctuations within the eddy core are random, and thus provide the transport mechanism. The size and intensity (random velocity) of the turbulence can be measured by hot-wire anemometers. Relations exist that suggest how these space measurements can be translated to mixing. However, the rigor of these relations at conditions other than fully developed pipe flow is questionable. The use of the relations are complicated by the inclusion of the coefficient of drag of droplets in the case of liquid sprays.

Deterrent

Perhaps the greatest deterrent to the application of all formal mixing theory is that the final result only gives the mixture concentration at a fixed point in space, averaged over a long time. In contrast, combustion is a chemical process that requires intimate molecule-to-molecule contact. A few experiments and analytical studies are underway that attempt to determine the instantaneous structure of fuel-air mixtures, but so far no generalized results are available. Crude but sometimes illuminating approximations can be made of the instantaneous fuel-air structure by analyzing the time for molecular diffusion to proceed across characteristic eddy sizes.

Influence of Nozzle Expansion Processes on Net Thrust



Note: For stoichiometric hydrocarbon fuel-air mixtures.

Combustion processes have also been treated with varying degrees of sophistication, some with considerable success. The composition of combustion products for more common fuels can be deduced exactly by well-known chemical equilibrium calculations over the entire range of fuel-air ratios and inlet-flow conditions of interest. Machine computing procedures give results rapidly even when a large number of chemical constituents are considered. We leave exactness behind when we depart from the thermodynamics of combustion-equilibrium calculations and enter the realm of rates of combustion processes.

The generalities of ramjet combustion kinetics are similar to the pattern of all chemical conversion steps. Rate is influenced by the concentration of the forward- and rearward-reacting species. The actual completion of a chemical reaction is controlled by the "energetic collision" between reactants. The energy required is often called activation energy. Temperature is used to indicate the number of gaseous reactants possessing the required activation energy. As temperature is increased, a large increase in the "energetic" particles occurs. (The tail of the Maxwellian distribution curve.) Reaction rates can be described by terms that are dependent on concentration of reactants and an expression related to the number of particles containing sufficient energy to react. As the rate expressions are made more rigorous, several other terms dealing with probability and effectiveness of collision appear.

A large number of possible reaction paths exist in processes as complicated as fuel-air combustion; the number of reactants and products also change along the paths. Complex combustion intermediates are formed; and activation energies of many of the intermediate species are not known. The influence of mass and heat transport cannot be properly treated in the heterogeneous process of ramjet combustion. Exact solutions are only now starting to be made known for the simplest flames. No exact solution of ramjet combustion by use of reaction kinetics appears probable.

Cruder approximations based on combustion kinetics have been used with some success. Assumptions are made that some simple reaction or simple set of reactions are rate controlling (slow with respect to other reactions or transport processes). The gross rates can then be measured in small-scale controlled experiments over a wide range of conditions. The degree of success in using rate data from small-scale equipment improves as it becomes functionally similar to the full-scale application.

Despite the shortcomings of much of the basic combustion research, information from research has been used to develop each step of the combustion process to a high degree of reliability.

Basic Combustion Principles

Application of basic combustion principles can be illustrated in the ignition process. Both theory and experiment establish the following as conducive to reliable ignition: Homogeneous fuel-air mixtures, near stoichiometric proportions, high pressure, high inlet temperature, low directed velocity, low turbulence, and low ratio of cold surface to gas volume. Quantitative values of electric spark energies required for ignition have been established for variations in many of the preceding conditions. The trends are consistent with combustion theory. The ignition energy requirements of a pyrophoric chemical igniter is also consistent with combustion theory.

At higher Mach numbers more commonplace fuels become pyrophoric. The spontaneous-ignition temperature and associated ignition delay have been measured for a variety of fuels. The spontaneous-ignition characteristics of simpler injection systems can be related directly to the simple reaction-rate theory, thus giving designers theoretically justified rules for extrapolation of data to new conditions.

After ignition, the flame must be

stabilized in some defined region in the combustor. Typical stabilization devices are perforated cans (similar to a turbojet combustor) and simple baffles (often a V-gutter). An injector-stabilizer may be used at high stagnation temperature.

Governing Principles

The governing principles of flame stability are relatively simple. It is postulated that a stable flame exists if the rate of heat generation in the flame equals or exceeds the rate of energy extraction. Expansion of this concept can be used to describe the flame stability of a simple baffle. The model assumes that a quantity of heat is trapped in a volume proportional to the recirculation zone of the baffle. This volume then heats a shroud of combustible mixture surrounding the recirculation zone. If the mixture in the shroud escapes the vicinity of the recirculation zone before the conditions of spontaneous ignition temperature and ignition delay times are met, the flame will blow out. Similar stabilization models are developed for can combustors and for ignition and stabilization on spray bars. Each of the models is consistent in that it introduces the interplay between heat transfer and reaction rates. The models are valuable because they relate geometrical requirements to ramjet combustor operating conditions. Typical results are seen either in the large-volume, carefully controlled can-type flame stabilizers used for high-altitude low-inlet-temperature conditions or in the crude spray bars used at high-inlet-temperature conditions.

The complex chore of completing reaction processes requires time and thus combustor volume. The best use of this volume results if the rate of addition of unburned mixture is carefully scheduled, so that maximum reaction rates are maintained.

The schedule of adding fuel-air mixture to a can-type combustor is one case where a relatively rigorous chemical-rate theory can be used. For example, assume that (1) the kinetics of the combustion process are much slower than the mixing processes, (2) the combustion and mixing processes take place at constant pressure and in a constant area combustor, and (3) the reaction rate is of the following form: rate $\sim C_F^a C_o^b\, e_{\exp} - E/RT_R$, where C_F and C_o are concentrations of fuel and air raised to the arbitrary exponents a and b. The exponential term contains an activation energy (E), the reaction temperature (T_R), and the gas constant (R).

A simple algebraic solution of the equation specifies that the fuel mixture should be added linearly. Conditions of maximum reaction rate will then be maintained irrespective of activation energy or exponential dependence of fuel-air concentration. Similar simple solutions result for variations in assumption (2). The actual length required cannot be specified within one or two orders of magnitude, but the manner of mixture addition (for the assumptions made) is explicit.

The execution of carefully programmed rates of fuel-air addition require some precision in hardware fabrication. Can-combustors or their equivalent are usually used for these applications. The openings in the combustor are adjusted to provide the desired flow areas. Empirical relations of discharge coefficients for many types of openings, various external flow-fields, and pressure drops across the combustor are available for this use.

The careful design and tailoring of combustors permit effective space utilization and efficient operation at severe operating conditions. As combustion conditions become less severe, it is usually possible to open up the combustor. For example, air or fuel-air mixture may be dumped through large slots at the rear of the combustor. Conditions conducive to better combustion, such as increases in temperature and pressure, induce severe heating problems. So not only is it permissible to "open up" the combustor, but often it is necessary in order to improve combustor reliability.

Attempts to classify combustors into "can" or "baffle" types are often made. But both tend to reduce to similar appearing devices when developed to meet a particular set of operating conditions.

Combustors designed for operation at very high Mach numbers are neither can nor baffle. They are nothing more than simple fuel injectors. Reaction rates cease to limit the oxidation process in the combustor. Attempts are made to mix the fuel with the air as rapidly as possible since quenching of reaction does not exist. Decisions on the combustor designs are almost completely dictated by the problem of high heat-transfer rates to the injector and combustor walls. Chemically stable fuels possessing a high cooling capacity must be used.

A combustor that develops a high chemical combustion efficiency will not always produce a high thrust efficiency. A uniform homogeneous mixture must be isentropically expanded through the nozzle at equilibrium composition to produce theoretical performance. A poor combustor-outlet-temperature profile—where 30 per cent of the combustion products are at 1200 R, 30 per cent at 2700 R, and the remainder at 4000 R—uses 12 per cent more fuel than a combustor producing a uniform temperature profile. A parabolic profile varying from a 1000 R wall temperature to a 4000 R core temperature requires 8 per cent more fuel than a flat temperature profile.

The losses due to temperature nonuniformity increase as the average fuel-air ratio of hydrocarbon fuels approaches stoichiometric. These results, though representative, should not be overgeneralized; they are related to particular fuels and inlet conditions. Composition and temperature of combustion products should be considered in a "time sense" as well as spatially. Existence of locally rich pockets of combustion gases sweeping through the nozzle will quickly induce severe performance losses.

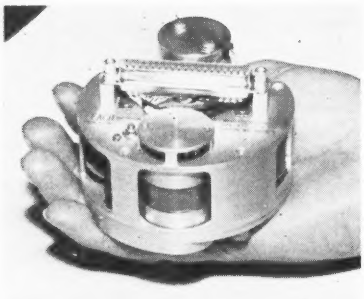
The expansion processes assume great importance at the higher flight speeds. If the dissociated molecules existing in the combustor do not recombine in the nozzle, large thrust losses occur. The graph on page 88 illustrates the seriousness of the problem. Net thrust drops 20 per cent at Mach 7 if the combustion products remain frozen at combustor composition during expansion rather than following thermodynamic equilibrium. The net thrust disappears slightly above Mach 10 if there is no recombination in the nozzle. The contributing factors can be easily surmised from the graph.

Little Known

Unfortunately, very little is known about the specific rates of recombination in ramjet nozzles, so that it is not known whether frozen or equilibrium expansion takes place. Volumes of qualitative literature on the expansion process exist, but numbers don't. The same degree of confusion present in the kinetics of combustion reappears in the expansion process, compounded by the transient pressure, velocity, and temperature environment of the nozzle.

At the very high flight speeds the major heat-release steps that contribute to thrust occur past the nozzle throat. Then, technically, ramjet combustion is predominantly supersonic. The combustion process is then firmly interwoven with expansion processes. The practicality of operation at these conditions and of this form of heat addition will not be established until the critical high temperature expansion experiments are performed.

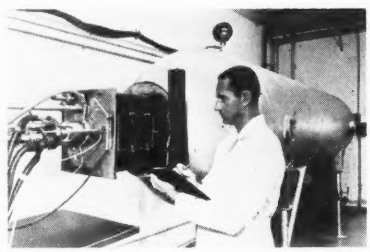
New equipment and processes



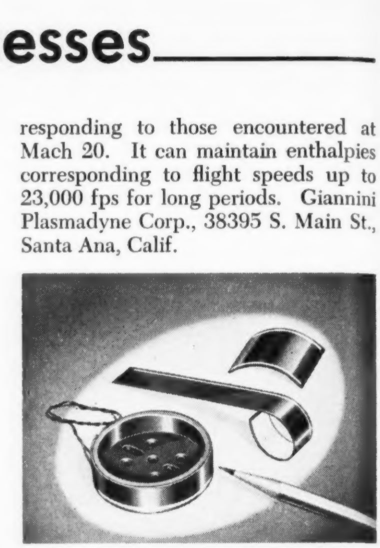
Miniature Tape Recorder: This 24 oz recorder operates without shock mountings under vibration of 15 g (5-2000 cps) and in impact of 2000 g. Diameter, 3.375 in.; length 2.5 in; tape speeds in 7 increments from 0.25 to 15 ips with 60 in. of tape; tape widths, 0.5 and 1 in.; power requirements, 24 v d.c.; wow and flutter, less than 1 per cent. Leach Corp., Compton, Calif.

Moisture Monitors: Type 26-350 series high-pressure monitors rapidly and accurately measure trace quantities of moisture in gases, gaseous mixtures, and vapors at sample pressures up to 10,000 psig. They verify dryness of bottled breathing oxygen, check compressed air used to drive missile turbines, and test moisture in pneumatic control systems and bottled cylinder gases. Consolidated Electrodynamics Corp., 300 N. Sierra Madre Villa, Pasadena, Calif.

Flame Photometer: The B-A direct-reading flame photometer is used to determine the concentration of sodium and potassium in samples of blood and other biological fluids. The instrument needs no galvanometer, uses ordinary city or manufactured gas, is portable, has an internal standard, and is easily calibrated. Baird-Atomic, Inc., 33 University Rd., Cambridge 38, Mass.



Hyperthermal Wind Tunnel: This continuous-arc Plasmatron tunnel with plasma-jet head coupled to an evacuation chamber gives thermal effects corresponding to those encountered at Mach 20. It can maintain enthalpies corresponding to flight speeds up to 23,000 fps for long periods. Giannini Plasmadyne Corp., 38395 S. Main St., Santa Ana, Calif.

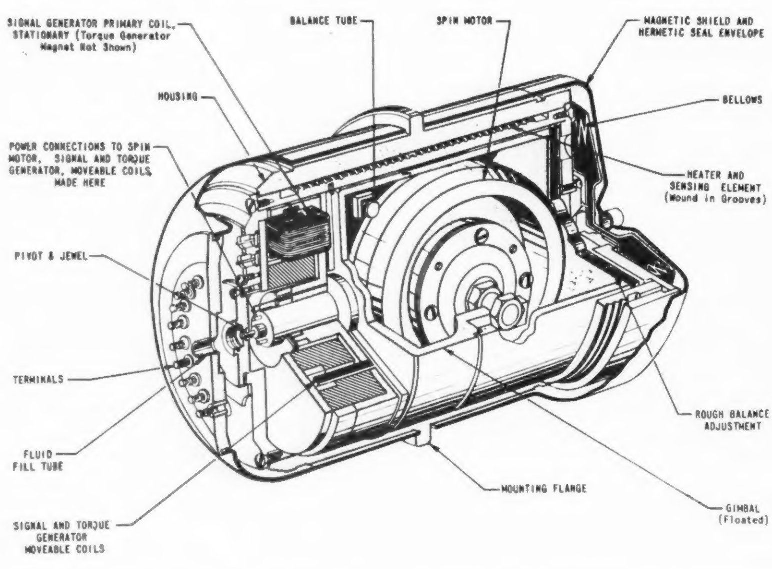


Contour Photocells: Three-dimensional selenium photocells which take almost any form offer new design possibilities in photoelectric devices. For instance, formed into a photosensitive cam, the light sensitive cells may be used as a form of nonlinear-function generator. International Rectifier Corp., 1521 E. Grand Ave., El Segundo, Calif.

Servo Assembly: For designers of automatic null balance systems, this servo offers a Holtzer-Cabot 4-pole, 60-cycle motor, drive coupling, shaft, bearings and gear drive, digital counters, and one or more output potentiometers, with synchro output and Coleman Decimal Digitizer optional. A limit stop prevents damage to the balance potentiometers due to off-scale inputs. Daytran Electronics, Manhattan Beach, Calif.

Noise-Proof TV Camera: Designed to operate in noise environments up to 145 db without an acoustical housing, and with a housing successfully used in sound levels above 190 db, the 7-lb Model 1986CN camera withstands atomic radiation, heat, cold, and hazards of accidental explosion. It features a video-signal amplifier with subminiature tubes mounted in a heat sink. Kin Tel, Div. of Cohu Electronics, 5725 Kearny Villa Rd., San Diego 12, Calif.

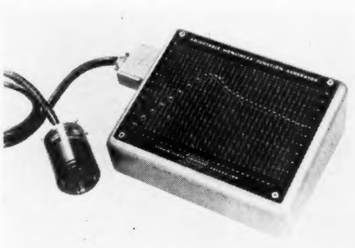
Tritiated Titanium Targets: A new process gives thin films of tritiated titantium on stainless steel or molybdenum—coats approximately 0.7 microns thick, on a 2 mil background, and containing 1 curie of titanium per sq in. This coating produces an ion current in excess of 10^{-7} amp/sq in. in air, and absolute beta emission greater than 10^{-9} amp/sq in. Radiation Research Corp., 1114 First Ave., New York 21, N.Y.



Floated Gyroscope: Designed for inertial guidance and navigation systems for missiles, satellite launchers, and other vehicles now in development, this hermetically sealed integrating (HIG) gyro (GG 37B) has a minimum operating life of over 1000 hr with drift remaining in a specified range—an order of magnitude better than those currently used. It can withstand severe conditions of temperature, shock, and magnetism. Minneapolis-Honeywell Regulator Co., Aeronautical Div., St. Petersburg, Fla.

Fuel Control System: This "package" fuel control system, developed for the Northrop T-38 supersonic trainer, consists of three motor-driven rotary-plug shutoff valves incorporated in a manifold. All valves are in one bay, simplifying inspection and maintenance. Repairs can be made without removing fuels from lines or tanks. General Controls Co., 801 Allen Ave., Glendale 1, Calif.

Horizontal Vibration Table: The Model EP239 oil-film "slippery table" reduces "cross talk" in vibration tests. The unit consists of a 5000-lb block of steel 36 in. sq, with a top surface Blanchard-ground to at least a 32 finish and hard-chrome plated. The block rides over a 12 in. deep tank which collects oil as it drains from the top surface. Test specimens go on magnesium slip plates. Mantec Div., Wyle Mfg. Corp., El Segundo, Calif.

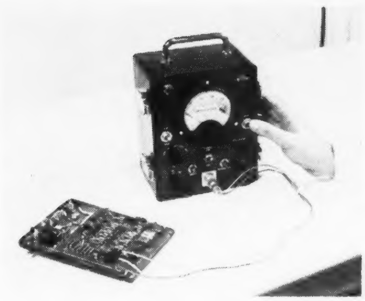


Ballistic Wind Computer: A compact computer, developed by the U.S. Army Signal Research and Development Lab, can determine ballistic wind effects directly from pilot-balloon data. It incorporates two adjustable nonlinear function generators developed by Perkin Elmer. Vernistat Div., Perkin-Elmer Corp., Norwalk, Conn.

Fuel Filter: A three-stage process that removes water and contaminants from fuels is used in 600-gpm Permadry units for the Air Force. The fuel passes through a synthetic fabric which removes large particles, then through a tubular Perma-Maze unit, and finally through a fiber glass unit. Permanent Filter Corp., 1800 W. Washington Blvd., Los Angeles 7, Calif.

Multipurpose Trailer: The MHR 12/M atomic bomb trailer designed for the Air Force is constructed of aluminum, including accessory parts and axles. It has 48 rotating tie-down rings, 5 tool boxes, air hydraulic brake and breakaway brake, telescopic draw bar, air springs, removable stake racks, hinged hatchways, hand parking brake, and retractable storage legs. It will support a normal load of 4000 lb. United Mfg. Co., 5250 Dobecknum Ave., Cleveland 2, Ohio.

Transistorized Recorder: Used in conjunction with radar tracking stations at Patrick AFB, and at strategic islands along the Altantic missile-tracking range, a new high-speed data recorder automatically stores information on magnetic tape in either coded decimal or coded binary at rates up to 30 samples or blocks per sec. Technitrol Engineering Co., 1952 E. Allegheny Ave., Philadelphia 34, Pa.



Transistor Tester: This device checks the performance of transistors within their circuits without turning on equipment power. It is being made for the Navy, but a commercial model will soon be available. Philco Corp., 4700 Wassahickon Ave., Philadelphia 44, Pa.

Cathode Coating: Sylvania has developed a technique for "wrapping" uniformly thin carbonate coats ("Sarongs") about vacuum-tube cathodes. This technique, which improves noise level and quality of emission, will see wide use in Sylvania tubes. Sylvania Electric Products, Inc., Emporium, Pa.

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Ferrotron ferromagnetic materials. The Polymer Corp. of Pennsylvania, Reading, Pa.

Rubber-Metal products. Clevite Harris Products, Inc., Lockwood Road, Milan, Ohio.

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Hufford spin-forge machine. Hufford Corp., El Segundo, Calif.

Micropoint tool grinder. De Vlieg Machine Co., Fair St., Royal Oak, Mich.

Pillow block and flange bearings. Hoover Ball and Bearing Co., Ann Arbor, Mich.

Multichannel strain gage recording and plotting systems. B&F Instruments, Inc., 3644 N. Lawrence St., Philadelphia 40, Pa.

Questions and answers on electron microscopes. Philips Electronics, Inc., Instruments Div., 750 S. Fulton Ave., Mt. Vernon, N.Y.

Gas regulators. Air Reduction, 150 E. 42 St., New York 17, N.Y.

Transistor digital subsystems. Tempo Instrument Inc., Commercial St., P.O. Box 338, Hicksville, N.Y.

Transistor-regulated and tube-regulated power supplies. Lambda Electronics Corp., 11-11 131 St., College Point 56, N.Y.

Thermocouple temperature millivolt tables. Thermo Electric Co., Inc., Saddle Brook, N.J.

Industrial enclosed switches. Micro Switch, A Div. of Minneapolis-Honeywell Regulator Co., Freeport, Ill.

Corona-type voltage regulators. The Victoreen Instrument Co., 5806 Hough Ave., Cleveland 3, Ohio.

Secsyn brushless generators and motors. Jack & Heintz, Inc., Cleveland 1, Ohio.

Cable assemblies. H. H. Buggie, Inc., P. O Box 817, Toledo 1, Ohio.

Printed circuit test point connectors. DeJur-Amsco Corp., 45-01 Northern Blvd., Long Island City 1, N.Y.

Nickel cadmium "button cell" batteries. Gulton Industries, Inc., Alkaline Battery Div., Metuchen, N.J.

Right-angle pin and socket connectors. DeJur-Amsco Corp., 45-01 Northern Blvd., Long Island City 1, N.Y.

El-Menco ceramic disc capacitors. The Electro Motive Mfg. Co., Inc., Willimantic, Conn.

Pulse transformers. PCA Electronics, Inc., 16799 Schoenborn St., Sepulveda, Calif.

1021 Frequency meter. Divco Wayne Electronics, Electronics Div. Divco-Wayne Corp., 9701 Reading Rd., Cincinnati 15, Ohio.

Unbrako socket screws, keys, dowel pins. Standard Pressed Steel Co., Jenkintown, Pa.

Plastic molding materials. Mesa Plastics Co., 11751 Mississippi Ave., Los Angeles 25, Calif.

Adhesives, coatings, and sealers. 3M Co., Adhesives, Coatings and Sealers Div., 900 Bush Ave., St. Paul 6, Minn.

Roto-Tellite-word indicator light. Master Specialties Co., 956 East 108 St., Los Angeles 59, Calif.

From the patent office

By George F. McLaughlin

Portable Ground Cover Protects Launching Sites

A patent has been granted for a system which minimizes soil erosion and other damage associated with ground-launched rockets. The launching blast of gases from rocket projectiles devastates exposed ground area near the launcher. This is particularly objectionable in portable launching equipment for ordnance rockets, since the resulting clouds of dust and dirt handicap the operators, injure the launcher, and disclose the location of the battery. Severe soil erosion, moreover, renders portable launching equipment unstable, and makes it difficult to drive a vehicle close to the launcher to deliver ammunition.

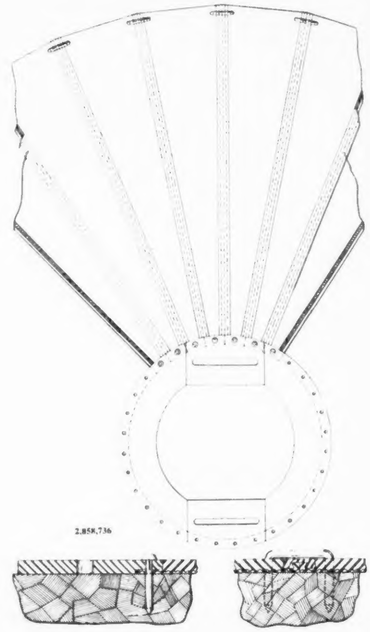
Portable ground covers made in accordance with this invention resist both inclement weather and the heat, flame, and abrasion resulting from launching rockets.

These covers, which withstand a great number of consecutive firings, are composed of flat sections which can be assembled at the site. The sections are formed of rubber-like material reinforced with fabric. This composition minimizes stretching and displacement of the cover by the force of the launching blast.

Sections have sufficient flexibility to conform to the ground's surface, and individual sections are replaceable if the cover structure is damaged in spots. Sections are formed and assembled so that, regardless of the direction of missile firing, the junction between adjoining segments exposed to the blast extends in the direction of blast force.

At its outer edges, the cover is secured to the ground by inverted U-shaped stakes at the corners of each section. The ground-engaging side of each section is reinforced with several plies of stretch-resistant fabric impregnated with rubber and vulcanized to the bottom surface of the sections. The plies strengthen the sections against stretching and minimize flex cracking. One suitable fabric is the square-woven duck commonly used for rubber conveyor belts. The upper surface of each strip is reinforced with similar fabric to minimize distortion of the strips when subjected to heat from propellant gases.

The material for forming the sections, connector strips, and segments of the central member is a rubber compound resistant to heat, flame, and abrasion. Compounds satisfactory in these respects include the types of material used for automobile tire treads. The sector-shaped mat sections and the central member are about 1 in. thick.

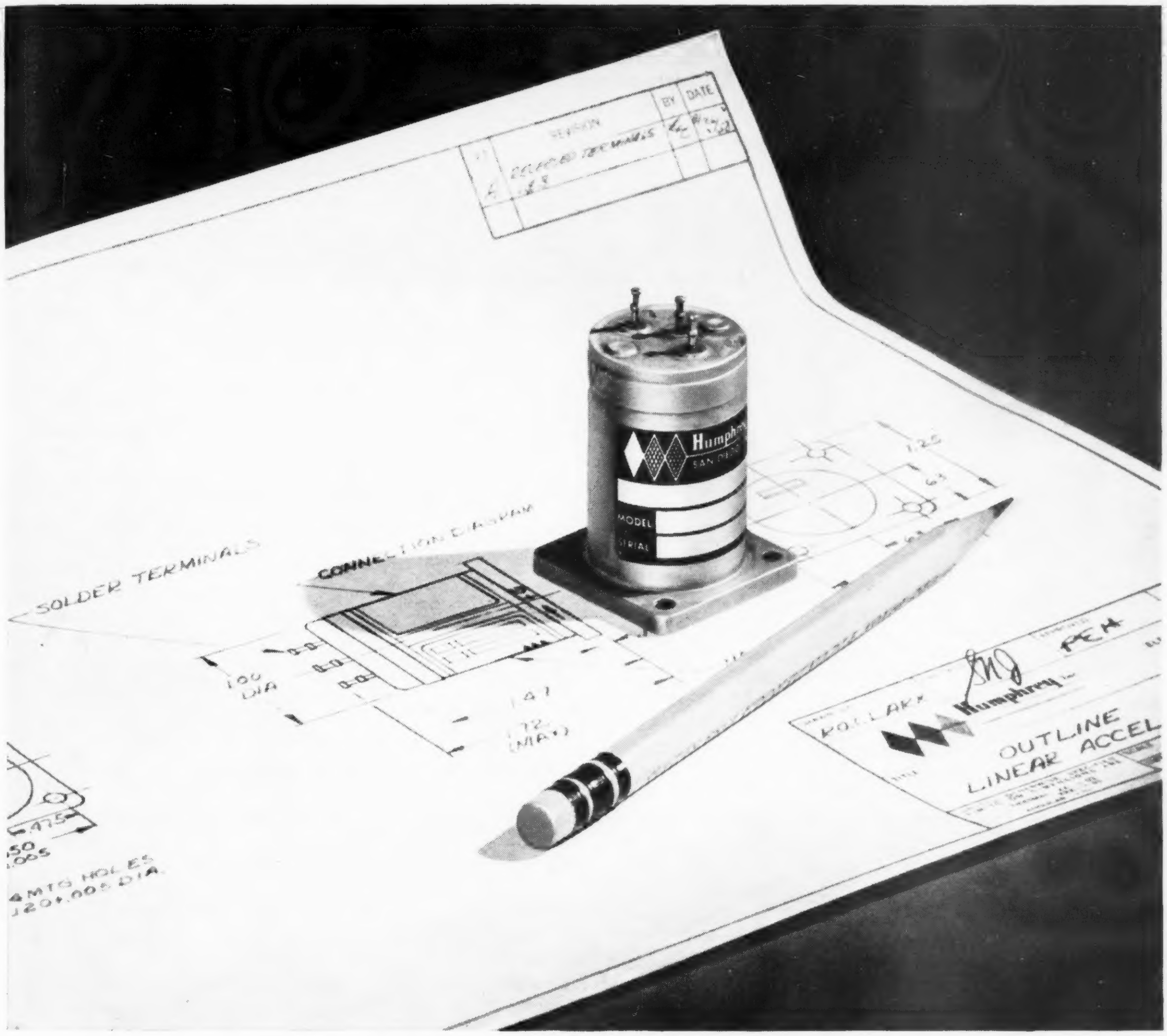


Plan view shows portion of assembled portable structure and cross-section of ground cover for launching rockets.

Portable Cover for Rocket Launching Equipment (2,858,736) Ray O. Hendrix, Cuyahoga Falls, Ohio, assignor to The B. F. Goodrich Co.

ITT Labs President Receives Four Patents

Henri Busignies, president of ITT Labs, who holds over 100 patents in electronics and related fields, has received a patent on long-range communication using metallic chaff or ionized gas as a radio-signal reflector, a patent on splitting a radar image into separate displays, and two patents, shared with three ITT engineers, on a spectroanalyzer for medical research.



NEW SUB-MINIATURE ACCELEROMETER...

full-size performance in the smallest package yet

This new Humphrey sub-miniature accelerometer with potentiometer pickoff is only one inch in diameter and less than one-and-one-half inches long. It is ideal for precision inertial sensing in minimum space.

UNIQUE DESIGN

This new instrument, known as the LA29-0100 series, employs a unique integral weight and dry-gas damper combination. Simplified design with minimum number of parts reduces cost and improves reliability. It is available in a variety of acceleration ranges and potentiometer characteristics to fit your requirements.

FOR TOUGH ENVIRONMENTS

These accelerometers are hermetically sealed, dry-gas filled instruments containing no plastic or other materials affected by high temperatures. Performance is practically unaffected by temperatures ranging from −75°F to +200°F. Satisfactory performance may be obtained at temperatures to 400°F. The LA29-0100 will operate well under the most severe vibration and shock conditions. Weight is approximately four ounces.

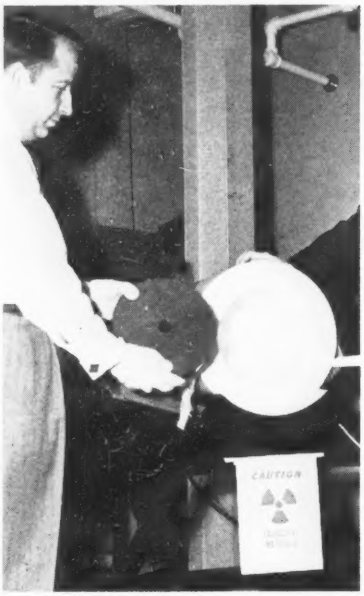
Humphrey welcomes the opportunity to discuss your accelerometer requirements with you. Write or phone today.

Humphrey Inc.

ELECTRO-MECHANICAL INSTRUMENTS

DEPT. A-49, 2805 CANON STREET • SAN DIEGO, CALIFORNIA

Reactor for Student Training at Texas Univ.



This small subcritical nuclear reactor, built by Lockheed's Georgia Div., will be used in the new nuclear engineering curriculum being developed at the Univ. of Texas with the aid of AEC. The reactor employs a core 10 in. in diam and 14 in. long, shielded by either polyethylene or graphite reflectors varying in thickness from 3 to 10 in.

Amateur Rocketeer

(CONTINUED FROM PAGE 33)

Corp.; and S. S. Naistat, Becco.

The impetus which got the program started was the large influx of mail from amateur rocketeers asking for information, as well as the fact that many of the ideas presented for comment indicated very hazardous propellant preparation, loading, and firing.

Buffalo Museum Cooperates

Through the generosity and the continued cooperation of the Buffalo Museum of Science and its director, Fred Hall, an auditorium was made available without cost. The auditorium can accommodate an audience of 500 and is equipped with all the necessary aids, such as movie and slide projectors, a public address system, etc. Since the auditorium was available on Saturday afternoons during the school year, this time was chosen for the meetings. It was also decided to use local people for all but one program and to show a movie on each occasion because there was no way of estimating the age-range of the audience which would be attracted. Programs were planned for an audience at the senior high school level.

Program

The series ran as follows:

1. Introductory Meeting; Movies—"A Moon is Born" and "Road to the Stars"
2. History of Rockets; Movie—"X Minus 80 Days"
3. Jet Propulsion Principles; Movies—"ABC of Jet Propulsion" and "Bell Vertical Takeoff and Landing Jet Airplane"
4. Rocket Propellants; Movie—"Basic Solid Propellant Rocket Engine Principle"
5. Rocket Powerplant Testing; Movie—"CAL LaCrosse Missile"
6. Rocket Safety; Luncheon, presentation of Contest Awards, Rocket Firing at Bell Aircraft Corp.

Along with the programs, the Section sponsored two contests—one for senior high school students, calling for a 2000-word essay on "Rocket Safety," and the other for junior high school students, calling for construction of a cutaway model of the Vanguard rocket and a Vanguard scrapbook.

At the first meeting, support for the project was expressed by Joseph Manch, Buffalo Superintendent of Schools; Col. C. G. Underwood, Commander of the Army's Nike Defenses in the Niagara Frontier area; the CAA; the Erie County Sheriff's Dept.; and the Buffalo Police and Fire Depts.

At the meeting, Dewey Rinehart of Bell, president of the section, explained why the program was being given and also read the ARS policy with regard to amateur rocket experimentation, while Robert Roach outlined the programs for the next five meetings. The meeting drew an attendance of approximately 400 students, parents, and teachers.

At the second meeting, Bob Roach presented a brief history of rocketry from the Chinese "arrows of flying fire" to the present time. At the third session, Bill Swenson discussed the principles of jet propulsion, demonstrating them by means of air-filled balloons and the firing of a small solid propellant gas generator rocket on a thrust stand, with the strain gauge on a beam measuring the thrust, which was registered on a strip chart recorder. The audience was supplied with trajectory formulas and solutions obtained for a typical missile flight.

A group of speakers headed by Ralph Bloom discussed rocket propellants at the next meeting. Bloom provided a basic introduction to propellants, with Leo Goldschlag discussing hydrogen peroxide as a monopropellant and the handling characteristics of nitric acid and H_2O_2; Helmut Koehn of Linde demonstrating lox handling problems; Harry Claflin of Olin Mathieson covering high energy fuels; and Irving Osofsky of Cornell Aeronautical Lab discoursing on solid propellants.

At the fifth meeting, Dexter Rosen, former field test director for Bell at Holloman, discussed testing of the Rascal missile, pointing out that there was a lot more involved than just "pushing the button." A film on preflight Rascal operations highlighted the presentation.

At the final meeting, the audience was invited to a free lunch provided by donations from local companies in the rocket and missile field, and then proceeded to Bell's Wheatfield plant to witness the firing of medium thrust nitric acid-jet fuel rocket engine. Contest prizes were awarded the same day. In the senior high contest, two youngsters won subscriptions to Astronautics and copies of the book "Project Satellite." In the junior high contest, a $25 Savings Bond went to the winner.

Good Attendance

Attendance at the meetings was very satisfactory, never dropping below 200 throughout the series. In all, 397 students from 90 local high schools, as well as the Univ. of Buffalo and Canisius College, registered for at least one session. Their ages ranged from 8 to 21, with the majority in the 13 to 16-year-old category.

Every session stressed the point that there was a lot to learn about rockets and warned of the dangers involved in experiments with explosive propellants. To make these points sink home, copies of the program were distributed at each meeting.

The Section's Education Committee adopted the idea of a special course in rocketry because there just weren't enough people available to handle individual talks at schools and rocket clubs in the area. In addition, it was felt that parents did not know enough about the subject to help their children avoid accidents, and parents could not attend lectures during school hours. Adult attendance at the meetings more than bore out this belief.

Those who participated in the sessions found them very encouraging and stimulating, and it is hoped that in some small manner the Niagara Frontier Section has contributed toward awakening youngsters to possibilities for the future in the rocket and space flight fields.

In print

Rocket to the Moon, by Erik Bergaust and Seabrook Hull, D. Van Nostrand Co., Princeton, N.J., 1958. 270 pp., illus. $5.95.

In this brisk and ably written book, Erick Bergaust and Seabrook Hull, respectively editor and former associate editor of *Missiles and Rockets,* present the familiar panorama of theory and history that leads toward the conquest of space. Along the way they have woven in much new material, detail, philosophy, explanation, quotations, and fresh ideas from the lively minds of today's astronauts, and have also included considerable information about the state of astronautics in Russia.

But mere presentation of the space flight idea is not the primary reason for the book. The authors are also properly concerned about the role of government, and especially the U.S. Government, in the space age.

They are alarmed about the rate of our American progress along the road to space, especially in view of the advanced program of astronautics in Russia.

"To a large extent, the same casual, academic appreciation of space flight that prevailed (in the U.S.) in the pre-Sputnik era still survives," assert the authors. "Neither the officials in Washington nor the public who elected them to office yet fully appreciate the really basic signficance of space flight, satellites, moon rockets, Mars and Venus probes, etc.

"In this respect, at least, America's escape from earth depends on an escape from outmoded thinking in Washington and in certain vested portions of American industry."

Messrs. Bergaust and Hull see us as inevitably losing the space race unless we can get rid of complacency and technical naivete in high places, unless we cease thinking of space flight as a mere "postscript to aviation or ordnance," or "simply a tool for the scientist."

More and more, they declare, "aviation activities are getting a stranglehold on the new science of astronautics. . . The eventual outcome can only be to warp and stunt this new science to fit existing patterns of thought, organization, and facilities."

They point out that virtually no experienced rocket engineers or astronautical scientists have been appointed to top decision-making or policy-making jobs in NASA or ARPA. Top men in these agencies for the most part are either aeronautics experts or engineers or executives from other fields. Rocket and space men of recognized ability usually have been relegated to the hardware side of the picture.

"It took this country 35 years to get an Air Force. After WWI, air defense was a stepchild of the U.S. Army. This concept cost the U.S. billions of dollars in unnecessary expenditures by tying American aviation to strictly earthbound methods and principles and often to very restricted and inhibited thinking, research, and development.

"Are we about to repeat this short-sighted approach to building our Space Force? Tying spacepower to airpower, or to land or seapower, cannot be justified for any historic, industrial, or military reason. All three services are now scrambling to take over the spacepower capability, while some officers simultaneously scoff at it. Development of a true space capability. . . . has been delayed years by earthbound, seabound, or airbound thinking."

From these few excerpts, it will be apparent that "Rocket to the Moon" has something to say. It is a thoroughly readable book, in places an angry book, but stimulating and informative throughout. It is a book of interest both to the man who knows all about astronautics, and the reader who still wants to learn why it is taking the engineers so long to overtake the fiction writers in this field.

—G. Edward Pendray

BOOK NOTES

Fundamentals of Advanced Missiles, by Richard B. Dow (567 pp., John Wiley & Sons, New York, $11.75), aims to reduce the diverse principles and related applied science and engineering for missiles to a comprehensive discussion for a person with, say, two years of university-level physics. Roughly half of the book covers flight kinematics, fluid mechanics of propulsion and aerodynamics, and general dynamics, including control systems. The other half, taking advantage of this backdrop, goes into some statistics of kill probability, reliability, etc.; means for guidance—microwaves, infrared, and radar; and, finally, over-all guidance and missile systems. Although necessarily eclectic, this text, which is carefully written and edited, should help inform a tyro in the complex of science and technology brought to bear on guided-missile design.

RECEIVED

High-Temperature Effects in Aircraft Structures, edited by Nicholas John Hoff (357 pp., Pergamon Press, New York, $12). An AGARD publication, well-organized.

A Simplified Technique of Control System Engineering, by G. K. Tucker and D. M. Wills (303 pp., Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia, Pa., $5). Graphical methods of understanding and improving process control.

Jahrhundert der Raketen, by Heinz Gartmann (317 pp., Verlag Paul Muller, Munchen, 81.60 shillings).

The Story of Aviation, by David C. Cooke (264 pp., Archer House, distributed by Herman and Stephens, New York, $4.95).

Technical Societies Guide (32 pp., Industrial Publicity Association, 41 E. 42 St., New York 17, $3). On the presentation of papers and preparation of associated publicity; covers 36 societies.

The Unwritten Laws of Engineering, by W. J. King (50 pp., ASME; free from General Transistor Corp., Jamaica, N.Y.).

Professional Income of Engineers (Engineers Joint Council, New York; $3 from Engineering Manpower Commission, 29 W. 39 St., New York 18).

Spin Forging (34 pp., Marquardt Aircraft, Van Nuys, Calif.). An illustrated pamphlet.

A Bibliography of the Electrically Exploded Wire Phenomenon, by William G. Chace (69 pp., AFCRC Geophysics Research Directorate Bedford, Mass.; Apply to OTS, Dept. of Commerce, Washington 25, D.C.).

Space Handbook: Astronautics and Its Applications; Space Law; and other publications prepared under the auspices of House and Senate committees on astronautics and space are now available from the Government Printing Office, Washington 25, D.C.

Contributions to Stratospheric Meteorology (GRD Research Notes No. 1), edited by George Ohring. . .Project Prairie Grass, A Field Program in Diffusion, Vols. I and II, edited by Morton L. Barad (Geophysical Research Papers No. 59). . . (Geophysics Research Directorate, AF Cambridge Research Center; available to DOD and contractors through ASTIA and to others through OTS, Dept. of Commerce, Washington 25, D.C.).

Sales Manager's Guide to Southwestern Military Bases (20 pp., Los Angeles Chamber of Commerce, 404 S. Bixel St., P.O. Box 3696, Los Angeles 54, Calif.; $1).

A Guide to Nuclear Energy, y R. F. K. Belchem (77 pp., Philosophical Library, New York, $3.75). Description of reactors.

Radioactivity Measuring Instruments, by M. C. Nokes (75 pp., Philosophical Library, New York, $4.75). Aimed at high school teachers.

Problems in Technical Publication Management, by Roswell Ward (22 pp., Roswell Ward, Bantam, Conn., $3.50). A pamphlet.

The Canadian Astronautical Society (15 pp., De Havilland Aircraft of Canada, Guided Missiles Div., Downsview, Ontario, Canada; on request). The brochure describes the organization and activities of this relatively new professional society, which is a member of IAF. The Society offers other literature, e.g., papers on an "Experimental Lunar Antenna" and the C.A.S. projet, Charm, a sounding rocket.

Ramjet Trends

(CONTINUED FROM PAGE 41)

hypervelocity ramjet.

Until recently, it had been concluded that the useful application of the ramjet engine was limited to speeds on the order of Mach 4.0. This conclusion was reached as a result of the manner in which the combustor temperature was thought to influence ramjet engine thrust. The high stagnation temperatures of hypersonic flight (stagnation temperatures of 4000 F are reached at Mach numbers slightly in excess of 7.0) limit the combustor temperature rise, and, it was believed, also limited available ramjet thrust.

The graph on page 41 shows variation in combustor temperature rise with Mach number for both a conventional fuel and an advanced fuel. Although the temperature rise approaches zero well in the hypersonic Mach number regime, the rapid drop-off with Mach number was thought to impose a severe penalty on ramjet performance, and it was concluded some time ago that about Mach 4.0 was probably the upper limit to the ramjet engine application. This conclusion was in error!

There are more ways of adding energy to the exhaust gas than is indicated by the temperature increase of the gas. Moreover, *energy addition* causes the acceleration of the air as it passes through the ramjet engine; it is really the basis for thrust, not merely temperature rise. With increasing Mach number a point in energy addition is reached where a significant increase in gas temperature can no longer be achieved.

But this does not limit the energy addition; for instead of causing an increase in temperature, the energy added is utilized in producing dissociation products. Instead of molecules, such as CO_2 and H_2O, which are the primary hydrocarbon-fuel exhaust gas products, fragments of molecules are produced. All this occurs without a significant increase in temperature. If, as the gases flow through the exit nozzle of the engine, these fragments can be recombined into the complete molecule, the energy it took to break them apart is recovered. An increase in exit gas velocity and engine thrust results. When considered from this viewpoint, the ramjet is not limited to even Mach 15.

The energy "locked in" during the dissociation process must be recovered to obtain the maximum thrust potential available from the ramjet at extremely high Mach numbers. Consequently, the probability of recombination of the dissociated combustion gases as they flow through an exit nozzle is a question of major interest at this time. The terms best used to describe this problem are *frozen* and *equilibrium* flow. The theoretical difference in thrust between frozen and equilibrium nozzle expansion depends, of course, on the fuel used.

Frozen-flow thrust estimates for a 3-ft-diam ramjet engine burning JP-4 fuel are compared to equilibrium flow case in the graph on page 41. The large effect on thrust level which occurs as Mach number increases is immediately apparent. The frozen-flow curve assumes that the exhaust gases are chemically frozen in composition at the entrance to the nozzle and that the gas properties remain constant as the gas flows through the exit nozzle. The equilibrium-flow curve, on the other hand, assumes that as the gases expand through the nozzle and the local temperature drops as a result of the velocity increase, the composition of the exhaust gases is in equilibrium at every point in the nozzle. Now, if the gas composition, and consequently the gas properties, adjust themselves at each point in the exhaust nozzle, the energy involved in the dissociation process is recovered. The question is, "Will this actually happen in the physical engine?"

Fortunately, the analytic studies and the limited experimental work carried on in this area are encouraging; and, it is anticipated that for a full-scale hypervelocity engine burning fuels of current interest, essentially equilibrium flow may be expected.

Military Applications

What practical form has the ramjet taken to date? Ramjet military applications fall into three general categories: Target drone, interceptor, and strategic vehicles.

Plover, manufactured by the Martin Co. for the Navy is an example of an early subsonic ramjet-powered target drone. It was to cruise for 26 min at an altitude of 20,000 ft. Some 600 Marquardt engines were produced for this program at an average price of slightly over $1000 per engine. It is interesting to note that the complete drone, including powerplant, autopilot, and electronic gear, was supplied to the Navy for less than the price of a competitive turbojet engine to do the same job. The ramjet on this drone was 20 in. in diam, weighed 120 lb, and was successfully flown at Mach 0.9. It developed about 2250 hp at sea level, and had a specific fuel consumption of 5.5 lb of fuel per hour per pound of thrust.

The Lockheed Kingfisher, adapted from the X-7 test vehicle, is a cur-

rent ramjet -powered target drone. As did the X-7, this machine holds the speed record for air-breathing engines. Powered by a single 28-in. ramjet engine, Kingfisher is recoverable and has a good reliability record.

Talos and Bomarc are two examples of the surface-to-air interceptor application of the ramjet. The Talos vehicle is an earlier development than Bomarc. It also represents a different design philosophy. The Talos engine and airframe are integral. The inlet to the engine is in the nose of the airframe and the engine exhausts at the base. Talos is about 20 ft long, 30 in. in diam, and weighs (less booster) 3000 lb. Talos has a range of over 65 miles, extremely high operational altitudes, and a supersonic speed capability. Talos was developed by the Applied Physics Laboratory of Johns Hopkins University for the Navy Bureau of Ordnance. Both the engine and airframe are produced by the McDonnell Aircraft Corp., under a prime contract held by the Bendix Aviation Corp.

Bomarc, an area defense surface-to-air missile, represents the pod-mounted-engine design philosophy. It not only flies faster and higher than the Talos but has several times the range. The airframe is produced by the Boeing Airplane Co., and it is powered with two 28-in.-diam Marquardt ramjets. An interesting size comparison between Bomarc and piloted interceptor aircraft can be seen on page 40. The ramjet missile has approximately twice the speed capability of the aircraft, and the reduction in airframe size achieved by removing the pilot is startling.

The third general category of ramjet military application is the strategic vehicle having either bombing or aerial reconnaissance as its mission. The North American Navaho is the only long range ramjet-powered vehicle falling into this category. Navaho was designed for a 5000 n. mi. range, cruising at Mach 3.0 and an altitude of approximately 75,000 ft. It was powered by two 48-in.-diam, integrally located ramjet engines developed by Curtiss-Wright. Navaho was a canard configuration with a delta wing, and weighed at takeoff, including booster, between 2000–3000 lb. This was the first supersonic long range missile powered with an air-breathing propulsion system. The ramjet engines for this vehicle passed development and preflight rating tests, and were flown with demonstrated 100 per cent reliability when the vehicle was boosted to the proper ramjet starting conditions. It is interesting to note that the B-70, the most

advanced bomber currently in the planning stage by the Air Force, flies no faster than Navaho.

Considerable ramjet progress has also been achieved abroad. The greatest activity seems to be in France, the birthplace of the ramjet. Two man-carrying, ramjet-powered airplane programs have been carried on in France, one by the pioneer ramjet experimentalist, Rene Leduc, and the other by Nord Aviation. The Nord-Griffon II Airplane, using an auxiliary turbojet engine for takeoff and landing, has reached Mach number 2.1 on ramjet power alone. Capt. Iven Kincheloe flew this airplane shortly before his untimely death, and was quite enthusiastic about combining the ramjet and turbojet powerplants in a man-carrying machine. He reported that transition from turbojet to ramjet and back to turbojet was easily accomplished.

France and Britain have both been active in applying the ramjet to a surface-to-air interceptor missile. This application is also receiving some attention in Sweden. The British effort, known as the Bloodhound missile, is the farthest along in development. Powered by two Thor BT-2 ramjet engines built by Bristol Aero Engines, Ltd., Bloodhound is reportedly 22 ft long and 21 in. in maximum diam, with a wing span of a little over 9 ft. It is carried in a portable launcher. The rocket booster takes the missile up to about Mach 1.5, and then the two nacelle-type ramjet engines take over and increase the speed to approximately Mach 3.0. The engine has a spike inlet, is 95 in. long, and has a diameter of 16 in. Bristol is currently working on an 18-in. diam version of the Thor engine.

The ramjet's extremely high thrust-to-weight ratio makes possible a very small, inexpensive helicopter. In the U. S., both McDonnell Aircraft and Hiller Helicopters have developed aircraft of this type. Abroad, the Dutch have seized upon this application and are marketing a small ramjet-powered vehicle known as the Kolibrie (Hummingbird). Because the rotor tip speed, and consequently the speed of the ramjet at the rotor tip, is relatively slow, the efficiency of the ramjet engine is quite low compared to other competing air-breathing helicopter powerplants. The range of a ramjet-powered helicopter will thus be low. Moreover, such a machine has only limited endurance. The Kolibrie helicopter has a top speed of 98 mph and a range of about 95 miles.

Ramjet activities have also been undertaken in Russia, where the initial effort dates back to 1936. By January 1940, subsonic flight tests were being made with conventional, propeller-driven, piloted test-beds. This work continued through 1948, and, it appears, paralleled the effort in the U.S. Recent Russian publications present analytic ramjet performance estimates to Mach 10.0 and support the feasibility of the hypersonic ramjet. Moreover, current Russian technical publications in the fields of combustion, aerodynamics, and control systems concerning hypersonic ramjet applications indicate a high degree of technical competence and an advanced state of the art.

Consistent with their emphasis on space flight and techniques for lifting heavy weights into space, the Russians have explored the boost application of the air-breathing ramjet since 1955. As early as 1952 (Jet Propulsion, July-August 1952), Tsien in the U.S. emphasized that air-breathing engines are a more efficient means of accelerating a vehicle through the atmosphere than a rocket, since the oxidizer is obtained free.

Nuclear Ramjet

The Russians have also published extensively on the utilization of nuclear energy as an energy source for ramjet propulsion but there is no indication of a nuclear-ramjet hardware program.

The attractiveness of the nuclear ramjet has resulted in the assignment by the U.S. Air Force of a feasibility contract to Marquardt. The success of such an engine depends upon advances in reactor technology. Should the feasibility of the nuclear ramjet be demonstrated, a supersonic air-breathing missile of unlimited range will be possible.

Moreover, the commercial application of the ramjet appears near. The ramjet-powered supersonic transport is being discussed both in the U.S. and England. Whether a 2-hr commercial flight between New York and London will become a reality in the next decade depends only upon its economic feasibility, for the technical knowhow already exists.

The ramjet engine has in the last decade outgrown its position as a laboratory oddity and reached mature stature as an air-breathing powerplant. Its future for both military and commercial application is bright. The ramjet is not only rapidly outpacing the turbojet as a high speed air-breathing powerplant, but shows signs of being competitive with the rocket as a hypervelocity engine for flight within the atmosphere. Recent advances in the state of the art may already have provided the capability of a Mach 7 ramjet.

Government contract awards

Space Vehicle Guidance

ITT has undertaken an ARDC contract to study space vehicle terminal guidance methods and problems.

Super Rocket Fuels Study

Esso Research and Engineering, working under a $1,264,000 Army Ordnance Corps contract, has formed a new unit to do advanced research aimed at development of improved solid propellants.

Instrumentation Planning For Pacific Missile Range

A Navy BuAer contract for instrumentation planning for the Pacific Missile Range has been awarded to Aeronutronic Systems, which will conduct and carry out the work in association with Cook Research Labs, Dunlap Associates, Eastman Kodak, and Page Communications Engineers.

$50 Million Hawk Contract

Raytheon Mfg. Co. has received a $50,731,000 Army contract for production of the Hawk missile system.

Test Sled Measuring System

ARDC has awarded Computer Equipment Corp. a development contract for a supersonic sled velocity measuring system, utilizing the company's space-time quantizer, that will evaluate test sled performance at Edwards AFB.

Eagle Guidance

Sanders Associates, Inc., has announced that it will design and develop part of the guidance section of the Navy's Eagle missile, under subcontract to Bendix Aviation.

Sub-Zero Coolants Study

AF has awarded Convair a study contract on the use of sub-zero coolants in machining various basic materials.

Bomarc Component

Lear, Inc., has received a $3 million follow-on order to supply coordinate converter systems which provide the basic gyro reference and airborne computer for the Boeing Bomarc.

NASA HEADQUARTERS R&D CONTRACTS

(Oct. 1, 1958 — Jan. 31, 1959)

PROGRAM	PURPOSE	CONTRACTOR	1959 OBLIGATIONS	TOTAL AMOUNT
AIRCRAFT, MISSILE, AND SPACECRAFT RESEARCH:				
Support of JPL plant	Research	JPL (CalTech)	$8,160,000	$8,160,000
Research	Molecular study	Yale Univ.	110,000	110,000
SCIENTIFIC INVESTIGATIONS IN SPACE:				
Sounding rockets	Partial support of Space Sciences Div. (Townsend)	NRL (Navy)	1,900,000	1,900,000
Earth satellites	Earth satellites (including Thor-Able boosters)	BMD (Air Force)	7,120,000	7,120,000
	Juno II boosters	AOMC (Army)	8,540,000	8,540,000
	Computing services (60%)	Bureau of Standards (Commerce)	80,000	80,000
	Alterations to buildings 5–7 Bellevue Annex	Alton Engineering Co.	130,000	130,000
	Partial support of Space Sciences Div. (Townsend)	NRL	2,000,000	2,000,000
	Research on rubidium frequency standards	Bureau of Standards (Commerce)	270,000	270,000
	Reduction analysis	Iowa State Univ.	10,000	19,320
Lunar probes	Lunar probe projects	AOMC	2,110,000	2,600,000
	Lunar probe projects	BMD	2,000,000	2,000,000
	Lunar probe projects	NDTS	200,000	200,000
	Computing services (30%)	Bureau of Standards (Commerce)	40,000	40,000
Deep space probes	Space probes	BMD	8,990,000	8,990,000
	Deep space study	ABMA	340,000	340,000
	Deep space study	JPL	1,300,000	1,300,000
	Computing services (10%)	Bureau of Standards (Commerce)	10,000	10,000
	Construction of addition to building No. 125 at JPL	Army Corps of Engineers	150,000	150,000
	Space probe instrumentation	Iowa State Univ.	40,000	292,000
Vanguard Div.	Support of the Vanguard Div., Space Projects Center	NRL	23,500,000	23,500,000
SATELLITE APPLICATIONS INVESTIGATIONS:				
Communications	100-ft inflatable sphere	AOMC	2,150,000	2,150,000
SPACE PROPULSION TECHNOLOGY:				
High energy fuel rockets	State of art work on rocket engines	WADC	430,000	430,000
	Develop 6000 lb thrust storable propellant system	JPL (CalTech)	2,000,000	3,400,000
1-Million-lb thrust single chamber engine	1,000,000-lb thrust rocket engine	Rocketdyne Div., North American Aviation	10,000,000	102,000,000
Nuclear rocket engines	Rover program	AEC	1,900,000	1,900,000

Jet Engine Testing Equipment

B&H Instrument Co. has obtained a $1,500,000 AF contract for modernization of jet engine testing equipment.

Tracker-Recorder Equipment

Army Signal Corps has awarded BJ Electronics a $500,000 production contract for transportable ground tracking and data-recording equipment constituting a Rawin Sonde System.

ADD-ON AND SUB-CONTRACTS

Rocket Catapults for B-70, F-108, and B-58—**Talco Engineering Co.**, in excess of $500,000, from NAA and Convair.

All-Metal Honeycomb Sandwich Components for B-58—**Solar Aircraft Co.**, about $1 million, from Convair.

True Airspeed Computer—**Servomechanisms, Inc.**, $656,859, from Martin Co.

Bomarc Coordinate Converter System—**Lear, Inc.**, $3 million, from Boeing.

Falcon Motor Cases—**Scaife Co.**, Wilson Bros. subsidiary, several hundred thousand dollars, AF add-on contract.

Precision Gyros for Nike-Hercules—**Sancor Corp.**, Siegler Corp. subsidiary, $650,000, from Consolidated Western Steel Co.

Atlas Ground Support Equipment—**Consolidated Electrodynamics Corp.**, $3.1 million, from Convair.

SYNOPSIS OF AWARDS

The following synopsis of government contract awards lists formally advertised and negotiated unclassified contracts in excess of $25,000 for each Air Force, Army, and Navy contracting office:

AIR FORCE

AFMTC, ARDC, USAF, Patrick AFB, Fla.

Increase in funds, $150,000, **General Dynamics**, Convair Div., San Diego 12, Calif.

Increase in funds, $40,358, **Perkin Elmer Corp.**, Norwalk, Conn.

Increase in funds, $29,944, **Dynatronics, Inc.**, 717 W. Amelia Ave., Orlando, Fla.

AMC Aeronautical Systems Center, USAF, Wright-Patterson AFB, Ohio.

Design, development, fabrication, and testing of a high performance inertial navigator, Hipernas II, $949,000, **Bell Aircraft, Autonics Div.**, P.O. Box 1, Buffalo 5, N.Y.

Hq, AF Cambridge Research Center, ARDC, Laurence G. Hanscom Field, Bedford, Mass.

Design digital facsimile technique using binary coded transmission of graphical weather charts, $37,502, **Tele-Dynamics, Inc.**, 5000 Parkside Ave., Philadelphia, Pa.

Development of proficiency measures for operator positions in the data processing subsystem of Sage, $49,962, **Educational Research Corp.**, 10 Craigie St., Cambridge, Mass.

Study of multiple beam interval scan-

(CONTINUED ON PAGE 118)

PROGRAM	PURPOSE	CONTRACTOR	1959 OBLIGATIONS	TOTAL AMOUNT
SUPPORTING ACTIVITIES:				
Tracking and data acquisition	Operation of earth satellite radio tracking and receiving stations for 6 mos. beginning 1/1/59	Government of Peru	75,000	75,000
Tracking and data acquisition	Operation of 2 earth satellite tracking and receiving stations beginning 1/1/59	Univ. of Chile	80,000	80,000
	Operations of Minitrack stations in South America and Cuba for 18 mos. beginning 1/1/59	Bendix Radio Corp.	600,000	Under negotiation
	Photo reduction equipment	Smithsonian Astrophysics Lab.	120,000	120,000
	Tracking and data reduction services	Smithsonian Institution	470,000	2,500,000
	LANGLEY RESEARCH CENTER			
AIRCRAFT, MISSILE, AND SPACECRAFT RESEARCH:				
Support of NASA plant	Modification of the impact basin to provide working space for Space Projects Center personnel	Endebrock-White Co.	60,000	60,000
	SPACE PROJECTS CENTER (LEWIS)			
SPACE OPERATIONS TECHNOLOGY:				
Manned space flight	Furnishing automatic flight control systems	Minneapolis-Honeywell Regulator Co.	140,000	140,000
High-energy fuel rockets	Propellant tank assemblies	Douglas Aircraft	110,000	110,000
	Furnishing rocket thrust chambers and necessary tooling	Solar Aircraft	180,000	180,000
	SPACE PROJECTS CENTER (LANGLEY)			
SCIENTIFIC INVESTIGATION IN SPACE:				
Earth satellites	X-248 rockets	Navy BuOrd	100,000	100,000
	X-254 rockets	Navy BuOrd	1,120,000	1,120,000
	Jupiter seniors	Navy BuAer	1,020,000	1,020,000
	XM-45 rockets	ABMA	90,000	90,000
	TX-33-20 rockets	ABMA	620,000	620,000
SPACE OPERATIONS TECHNOLOGY:				
Manned space flight	Atlas-D boosters	BMD	1,400,000	Under negotiation
	Atlas-D boosters	BMD	5,600,000	Under negotiation
	XM-45 rockets	ABMA	120,000	120,000
	Booster hardware, sets for TX-33	Aerolab Development Co.	70,000	70,000
	XM-19E1 rockets	Thiokol	110,000	110,000
	TX-33-20, TX-33-22 rockets	ABMA	2,200,000	2,200,000
	Part of Redstone boosters	AOMC	4,490,000	15,500,000
	Transport vehicles and launcher (S-91-4)	North American Aviation, Missile Div.	400,000	400,000
	Jupiter boosters	AOMC	2,740,000	4,450,000

Goddard Autobiography

(CONTINUED FROM PAGE 27)

to raise 1-lb final mass to great heights, with slow propulsion in the atmosphere (April 4, 1908).

Multiple rockets (Jan. 24, 1909).

Liquid H, O, N_2O_4 and CH_6 for rocket propulsion (June 9, 1908).

Continuous propulsion produced by liquids burning under pressure (June 11, 1908).

General theory of hydrogen and oxygen rocket (Aug. 10, 1910).

Reaction by streams of ions to furnish rocket propulsion (Sept. 6, 1906).

Use of solar energy in connection with electrostatic repulsion (July 1907).

Cooling of nozzle by liquid H and O (April 6, 1909).

Raising an explosively propelled apparatus to a great initial height by balloons (June 1907).

Camera sent around distant planets and returned to earth (June 19, 1908) and guided by the intensity of gravity at predetermined points of its path (June 24, 1908).

Steering automatically by photosensitive cells (Oct. 15, 1908).

Explosive sent to dark side of new moon giving specially colored light (Dec. 26, 1908) and observed as monochromatic light, on a Frauenhofer line, along with use of monochromatic light in locating a rocket returning from outer space (Jan. 21, 1908).

Circling a planet to decrease speed before landing (June 24, 1908).

Use of planes on rockets (April 6, 1909).

Production of H and O on the moon (February 10, 1910).

Automatic signaling from a planet (Aug. 18, 1908).

Means for neutralizing effect of decrease of gravity on an operator (Nov. 27, 1910).

Ion Experimentation

As a result of the ideas concerning the breaking up of atoms artificially by impact, of ions moving at very high speeds, and the motion of ions in closed paths, I experimented with a vacuum tube in which ions moved in closed paths due to a magnetic field while at Clark Univ., and later demonstrated the tube at the Physics Seminar at Princeton Univ., afterward obtaining a U.S. patent on the method (May 4, 1915, No. 1,137,964), entitled "Method of and Means for Producing Electrically Charged Particles."

Also, as a result of the attempt to obtain "reaction against the ether," or, in other words, reaction against a displacement current in free space, I obtained Patent No. 1,159,209, issued Nov. 5, 1915, entitled "Method of and Apparatus for Producing Electrical Impulses or Oscillations." This consisted of a means of obtaining forced vibrations of any frequency by means of an oscillating cathode ray beam, and resulted from a Wehnelt cathode ray tube, constructed at Clark Univ.

This idea led to some consequences which were highly important in shaping my later work. After having obtained my Ph.D. from Clark, choosing as a thesis the explanation of crystal rectifiers—not because I was particulary interested, but because I felt my previous studies on the conductivity of powders at Worcester Polytechnic Institute would be a help—I spent an additional year at Clark as an honorary fellow in physics, living on what I had saved while teaching for a year at WPI.

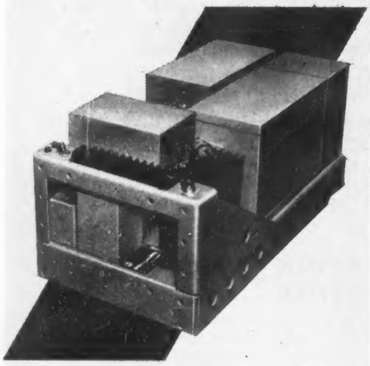
Two Interesting Essays

While at WPI, I wrote two essays of some interest. One, on the balancing of aeroplanes by use of the gyroscope, incidentally suggested bending of the wings in steering. The other, entitled "Traveling in 1950," concerned an idea for traveling in airtight cars in a vacuum, supported above and out of contact with a roadbed, and propelled by the action of magnets in the bottom and walls of both car and tunnel, there being an acceleration of 32 fps^2 during the first half of the journey and a deceleration of equal amount during the last half. A fundamental and important principle set forth in this essay was the continued acceleration of a body by forces which changed from attraction and repulsion as the body passed by the source of the force.

While at WPI, also, I wrote in 1907 a rather long article on the possibility of applying heat from radioactive changes in obtaining interplanetary transportation, the device being equivalent to a rocket. This was never published, and I still have the letter of rejection from W. W. Payne, the editor of Popular Astronomy at the time.

Before leaving for Princeton, the various methods were outlined in a careful discussion, and the theory of the multiple-charge rocket, conceived in 1908–09, was roughly outlined, along with the use of a lightweight solar energy engine, considered in 1907.

While at Princeton in 1912–13, I spent the evenings working on the theory of rocket propulsion, assuming that, with smokeless powder, and hy-



drogen and oxygen, an efficiency of 50 per cent could be secured. This I later found by experiment to be true. During the day I worked on an interesting physical problem not then explained by electrical theory—the positive result of force on a material dielectric carrying a displacement current.

While recuperating from a serious illness in May of 1913, I wrote the material for the two U.S. patents which cover the essentials of rocket propulsion, namely No. 1,102,653, dated July 7, 1914, and No. 1,103,503, July 14, 1914.

These two patents are worthy of special attention, in passing, for they give as nearly as possible an answer to the question as to what the "Goddard Rocket" is. The types of propellant that have given satisfactory results on the small-scale models have been so varied, and the methods of feeding successive portions of combustible or explosive materials into a combustion chamber have also been so varied, and yet proved so satisfactory, that I hesitate to limit myself to one particular apparatus and type of propellant. I prefer instead to consider the three broad principles covered in the claims of these two patents, namely (1) the use of a combustion chamber and nozzle; (2) the feeding of successive portions of propellant, liquid or solid, into the combustion chamber, giving either a steady or discontinuous propulsive force; and (3) the use of multiple rockets, each discarded in succession as the propellant it contains is exhausted.

1914—Work on Propellants

In the fall of 1914, while teaching part-time at Clark, I worked out the theory and calculations for smokeless powder and hydrogen and oxygen completely, and began experiments on the efficiency of ordinary rockets. Curiously enough, the initial mass needed to send 1 lb to infinity for hydrogen and oxygen at 50 per cent efficiency, namely, 43.5 lb, was close to that estimated roughly at 45 lb on Jan. 31, 1909.

Recognition of the importance of hydrogen and oxygen as a propellant, and the comparative ease of manufacture of liquid hydrogen and oxygen in comparatively inaccessible places where there was ice and snow and low temperatures, led to U.S. Patent No. 1,154,009, "Apparatus for Producing Gases." A further realization of the importance of repelling charged particles at a very high potential, and of light means for producing this potential, led to Patent No. 1,363,037, "Method of and Means for Producing Electrified Jets of Gas."

The experimental work which checked the conclusions set forth in this patent was carried out at Clark by two students during 1916–17, with the result that, at 20 lb pressure, a blast of air produced from 5000 to 10,000 v from 110 v d.c.

The chief experiments on which I myself worked in 1915–16 were concerned with the measurement of efficiency of common rockets, and of steel rockets provided with nozzles, the latter experiments being repeated, in part, in vacuo. These experiments were carefully written up and, together with photographs, were bound in a book entitled "A Method of Reaching Extreme Altitudes." The aim was to secure funds sufficient to permit the development and construction of a rocket having a large proportion of propellant to total weight. The use of smokeless powder appeared to offer the least experimental difficulty, and no other propellant was therefore mentioned.

The calculations for projection to an "infinite" distance were included, but, to avoid the appearance of too much speculation, it was considered best to suggest the sending of a mass of flash powder to the surface of the new moon, rather than to specify interplanetary navigation. The use of solar energy in decreasing transit time between planets was also omitted, as was use of the moon as a halfway station, and also the production of hydrogen and oxygen under pressure by electrolysis.

Nevertheless, as a hint of further possibilities, the following remark was made at the end of the manuscript:

"There are, however, developments of the general method under discussion which involve a number of important features not herein mentioned, which could lead to results of much scientific interest."

Smithsonian Lent Encouragement

A letter sent to the Aero Club of America regarding this manuscript brought no reply, but a similar letter addressed to the Smithsonian Institution gave some encouragement, and was accompanied by the request that the manuscript be sent for examination by a committee. This committee reported favorably, and a request for \$5000 for the construction of a model was granted.

Work was carried on chiefly in the Magnetic Laboratory at WPI, but in part also at Clark. With the entrance of the U.S. into the World War in 1917, it seemed desirable to have the development undertaken as a war

proposition, and after considering several plans, I went to Washington in the winter of 1917 and obtained the necessary support. From that time until June, the work was continued at WPI, and from June until nearly November, it was carried on at the Mt. Wilson Observatory shops in Pasadena, Calif.

With the devices developed and tested, and their possibilities, this document is not concerned. It is, perhaps, sufficient to say that, before the signing of the Armistice, a small multiple-charge rocket, using a few cartridges had been tested, operated satisfactorily and traveled straight—a distance of 60 or 80 ft.

On returning to Clark, Dr. Webster, Director of the Physical Laboratories, became interested in what I had done, and said that the matter should be published. He even went so far as to say that if I didn't publish a paper on rockets, he would. Under this stimulation, I asked the Smithsonian to publish the manuscript I had previously sent them, thinking this to be preferable to dividing the paper into several parts and publishing these in separate journals. They agreed to do so, provided it came out of my appropriation for rocket development. I agreed to do this, and the manuscript was published in the Smithsonian Miscellaneous Collections for 1919.

Inasmuch as I believed that some of the matters upon which I had worked should be mentioned in this publication, I included, in the form of supplementary notes, a discussion of secondary rockets, the use of hydrogen and oxygen, the probability of a collision with meteors, and a few other matters.

I received the reprints early in January 1920, and sent copies to a few friends. I though it odd that no notice of the work was taken by the press, as it seemed that the method was one that they might desire to feature. Several weeks passed, and I had nearly forgotten the press question, when one morning, I was startled to learn that the Institution itself (or, as I learned afterward, its press representative) had made of the paper the first real suggestion for contact between the planets.

From that day, the whole thing was summed up in the public mind in the word "moon-rocket," and thus it happened that, in trying to minimize the sensational side, I had really made more of a stir than I would if I had discussed transportation to Mars, which would probably have been considered ridiculous by the press representative, and doubtless never would have been mentioned.

Vanguard

(CONTINUED FROM PAGE 29)

irrevocably in the public mind—as much indeed as they were fixed in nature by the cyclic activity of the sun. We come then to the influence of these attitudes upon the design, the construction, and the launching of Vanguard vehicles.

There is, of course, a direct dependence of vehicle velocity upon specific impulse and mass ratio in a rocket. In Vanguard, once the propellants had been selected, minimum specific impulse values were specified for the three rocket motors. The question then arose, "Would they be realized in flight hardware?" If not, the difference would have to be made up in mass ratio. It was apparent at the outset that conventional structural margins would not suffice, that wherever possible a lighter component should be used. But how far to go? To what extreme?

Some Doubt

There was a valid fear, not expressed to the engine contractors, of course, that the specific impulses would not be realized. Hence a determined effort was made to save every possible pound, every possible ounce. In a choice between weight saving and reliability, reliability was likely to come in second, a close second perhaps, but at any rate, second. Not that any engineer knowingly selected an unreliable component, but rather that he said to himself, "An ounce saved is an ounce saved." There was less talk about reliability and more about adequacy. You wrote out the requirements for a component or a system and you designed to meet them. To exceed the requirements was somehow frowned upon—if you were going to do that, you should have set the requirements higher You did the best you possibly could within the time allotted, of which there was some but not enough. I do not refer here to effort or devotion to the job, which was of the highest quality, but rather to engineering standards, to the difference between adequacy and excellence.

When the choice arose between weight saving and simplicity, weight saving was usually the victor. Now there are many engineers who deplore the fear of complexity. They point to the many complex systems that have been designed and that do work reliably. But they tend to forget the setbacks that were encountered in the design and the "bugs" that had to be worked out. There is virtue in simplicity. The way to make a component most reliable is to eliminate it. A prominent American rocket expert has labeled Vanguard a sophisticated rocket. He is right.

A most unfortunate decision made early in the Vanguard program was to use production methods in design and construction. This should not be taken as criticizing the use of good tooling—and Vanguard has employed some excellent tooling—but rather the complex production procedures which make it difficult to incorporate a change. We have a tendency to use black and white arguments on this subject of design changes. Obviously, a project engineer who holds no rein on design changes is asking for trouble, particularly if he has a talented team. But to say that a change will be made only in response to a flight failure, to rule out changes in anticipation of failure, is, I think, the other extreme. We pride ourselves on being reasonable men and we say, "Let's seek the happy medium." Then we throw up our hands with—"But no one can define it."

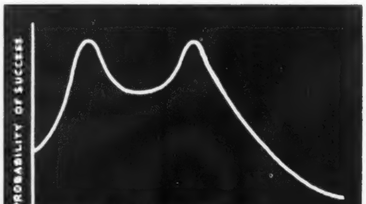
It seems to me that all of these arguments miss the point: That the mechanics of change should not be the major motivation against change. If they are, then it is too easy to rationalize, to be content with what we have.

The long countdown and the repeated countdown have become a way of life at Cape Canaveral. I have a theory about preflight testing which I cannot prove by analysis, but which is based rather on experience, my own and that of others.

The graph below relates the probability of success to the amount of preflight testing. You will notice that there are two peaks. The first occurs soon after the rocket is erected in the launch area. It is preceded by a minimum of testing—enough to demonstrate that all systems are working, not perfectly, but within reasonable tolerances. The second peak occurs after a long series of system tests including sometimes several captive firings.

During this process, many components fail and are replaced, with the aim of arriving at a vehicle that is as nearly perfect as human effort and schedule pressure will permit. Beyond this peak the curve drops asymptotically to zero due to the sheer aging of components. We may well debate whether one peak is higher than the other and if so which one. I do not know. But this I have found to be true, it is much more difficult to locate the second peak in time than the first.

The Shape of Preflight Testing



We may strive for the best possible rocket, but often we do not know when we have it. When a faulty part is replaced by a new one, the vehicle is improved. But what about the parts that cannot be replaced? What happens when we repeatedly fuel and defuel a rocket? Do the long count hours affect the efficiency of a crew or the judgment of its leaders?

We are inclined to grasp the leave-no-stone-unturned philosophy. It is as if we were saying, "If we do not succeed, at least we can say in clear conscience that we have done everything humanly possible." I suggest there is a higher wisdom. Let us admit that every launching of an experimental rocket is a gamble. Is it not better, then, to gamble when the odds for success are highest? Or are we more concerned to appear right than to be right?

Effect of Public Relations

We are told that it is only possible to launch a rocket at Cape Canaveral under conditions wherein the press and the public have a knowledge of what is happening. Moreover, it is not cricket to do otherwise. The public has a right to know. I wonder if anyone has considered the affect of this process on the men who prepare and launch the rocket? For it is upon them, in the last few hours, that the success or failure of the venture depends. Can they view their efforts in a sensible light when their work is portrayed as a sporting event replete with heroes and villains? I think not, and suggest that the public's right to know is adequately served by a full and honest account of what happened after it happens. And it is up to us, engineers and scientists, to make this point. How often recently have we been satisfied to do first and brag afterward?

We are involved in a serious business affecting not only the future of science but the political standing of our country. We have been criticized for lagging behind our principal competitor. Some people have become scared and have sought various excuses—our lack of attention to the

physical sciences, our preoccupation with high-finned automobiles, or simply that we started too late. There is a grain of truth in all of these statements, but they go far wide of the main point.

We have the talent to make a good account of ourselves. It is more a question of leadership and morale. I firmly believe that we will gain the lead in our field when, and only when, we learn to conduct our work quietly and with dignity.

Based on a paper presented at the ARS 13th Annual Meeting Nov. 17-21, 1958 in New York.

International Scene

(CONTINUED FROM PAGE 18)

services in that portion of the spectrum."

The 100–150 mc band is of particular concern to those working on the space radio problem because a great deal of the radio equipment used in present space projects has been developed for operation in this part of the spectrum. The Vanguard and Explorer satellites, for example, use frequencies in this band for vital purposes. The same is true for several major missile programs.

Expressions of grave concern have been received as to the possible dislocation of existing broadcasting and nonbroadcast, nongovernmental services in this region if there is encroachment on nongovernmental allocations in the 100–150 mc band.

The interests of the broadcasting industry and other nongovernmental users in the 100–150 mc band require careful attention. The present use of 108 and 108.03 mc in the Vanguard program and 107.94 and 107.97 mc in the Atlas program poses a threat to the FM broadcast industry, as is pointed out by Middlebrooks and several others interested in both space flight and broadcasting and industrial radio services.

John P. Hagen and John T. Mengel propose, however, that the temporary use of the 108 and 108.03 frequencies be continued, and ARS calls attention to the fact that continued operation on those frequencies probably will be required until firm, suitable allocations are established elsewhere in the 100-150 mc region.

In its Comments on the FCC's Fifth Notice of Inquiry, ARS urged the allocation of the 148–150.8 mc band for the space radio services, and in response to the 16th Notice, reaffirms this proposal and urges that any other frequencies selected by the Commission in the 100–150 mc region for space services be taken from those al-

located at present to government services.

The 150–1700 mc Area.—S. K. Hoffman, W. L. Rogers, Morton Alperin, John L. Sloop, and others, commented adversely on the lack of proposed frequency allocations in the band between 150–1700 mc. They point to the great ratio between frequencies in this band; to the present use of the 960 mc frequency by the Explorer satellite; and to the need for frequencies for space and satellite telemetry in the 200–300 mc region, and for tracking in the 450–500 and 900–1000 mc bands, as well as in other bands in the general area.

Martin Summerfield and Enoch J. Durbin point to the "gigantic research and development effort" and the "tremendous capital investment" for "procuring of telemetering air and ground equipment" in the 215–235 and 1435–1535 mc bands.

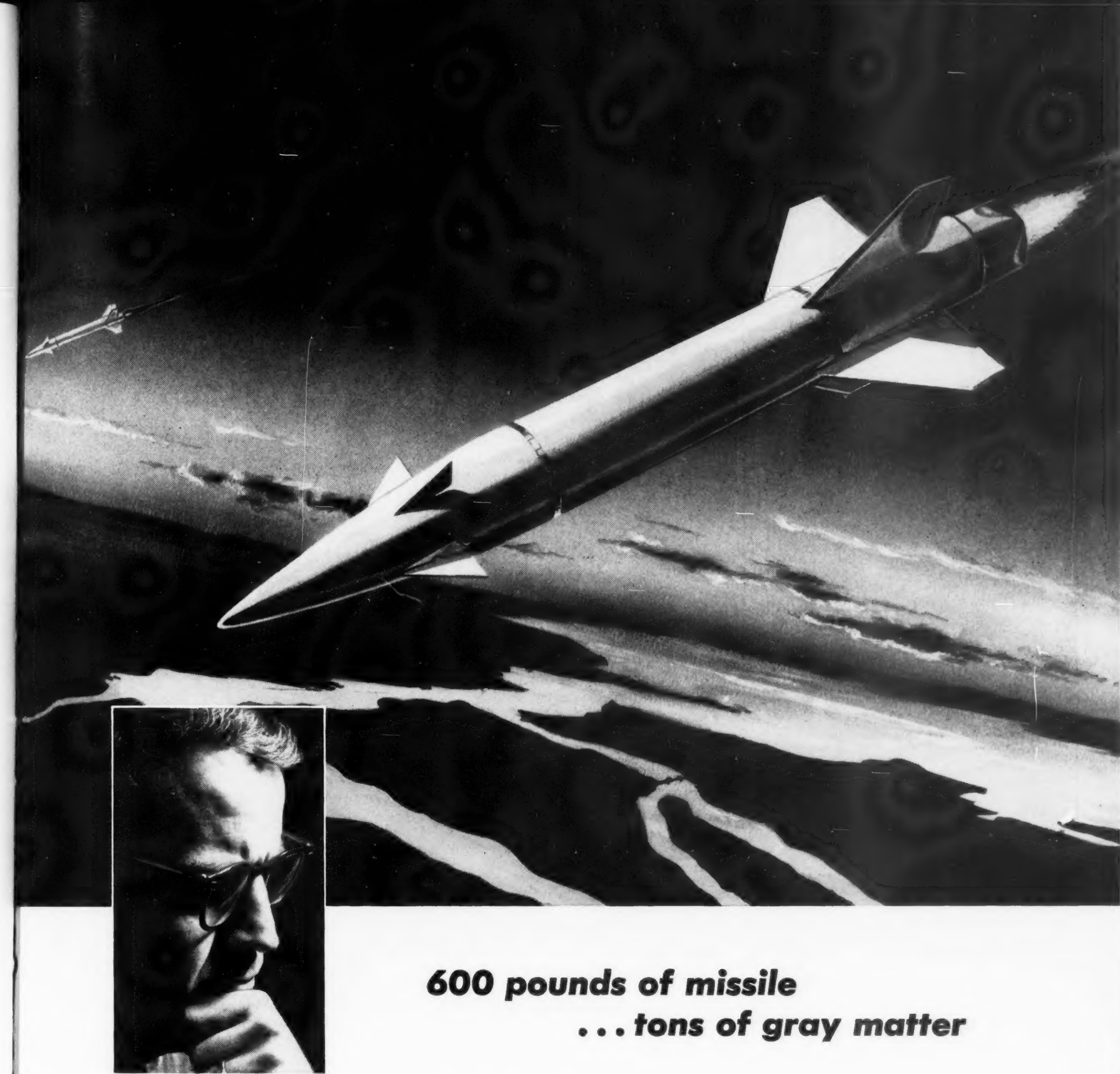
Allocation of frequencies in the following bands to the Space and Earth/Space Services is proposed by the Society: 216–220, 225–235, 250–260, 390–400, 410–420, 430–435, 960–970 and 1435–1535 mc.

The 1700–10,000 mc Area.—The FCC proposal to allocate 1700–1725, 1825–1850, 2275–2300, and 8300–8400 mc to the Space and Earth/Space Services has received partial approval from the Society, but as stated by Dr. Pickering, the proposed 25 mc bandwidths in this area will be inadequate. At least 50 mc, and preferably 75 mc, should be allocated for Space and Earth/Space radio services.

Dempsey and others see the need for allocations in the 3500–3900 and 4400–5000 mc bands and particularly in the lower end of the 5925-8500 mc band.

ARS urges in its comments that wider bandwidths be provided in the frequency areas mentioned above, and that consideration should be given to proposals for additional frequency space in the 2800–3000, 3500–3900, 4400–5000, 5400–5600, and 5925–8500 mc bands. Inasmuch as complex problems involving both governmental and nongovernmental allocations are raised in connection with the foregoing frequency bands, the Society points out that specific frequency allocations for radio services in those regions may involve frequency sharing and other devices to protect existing users.

Above 10,000 mc.—The Commission proposes to allocate the 15150–15250 and 31500–31800 mc bands to the Space and Earth/Space Services. Comments were received by the Society as to these parts of the FCC proposal. Clure H. Owen suggests that bandwidths in the order of 1000 mc be



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allocated in the two areas mentioned. The use of such bandwidths in the order of 1000 mc was proposed by ARS in its Comments on the FCC's Fifth Notice, and allocation of 1000 mc bands in the 15150 and 31500 mc region is considered wholly practical and highly desirable.

The Society therefore proposes that the following bands be allocated to Space and Earth/Space Services: 15150–16150, 31500–32500, and 80000–81000 mc.

Frequency Relation

Based upon data furnished by Drs. von Braun, Bailey, and Shapley, the Society urges that provision be made for a definite harmonic relation among the frequencies allocated for Space and Earth/Space services.

Transmission Control

ARS also calls attention to the potentially serious problem of controlling unmanned transmitters in space.

Seddon describes the problem vividly, as follows: "If the Vanguard's 'grapefruit' had more output power, it could be a nuisance for the next 200 years." He is referring, of course, to the transmitter operating in the small Vanguard satellite, which has an expected orbital life of 200 years. The solar power source has an equally long anticipated lifetime.

Middlebrooks also has expressed concern as to the effects of indefinitely long transmissions, and suggests that all space radio transmitters be equipped with silencing circuits.

ARS recommends that appropriate regulations be drafted which would require the regulation of transmitters employed in the new "space radio" services which FCC has proposed.

Japanese Rocket Society To Hold Space Symposium

The Japanese Rocket Society will holds its 1959 International Symposium on Rockets and Astronautics in Tokyo May 25–27. The meeting will be highlighted by the presentation of a number of technical papers and scientific exhibits. Hideo Itokawa is chairman of JRS.

Future for Hypersonic Ramjets

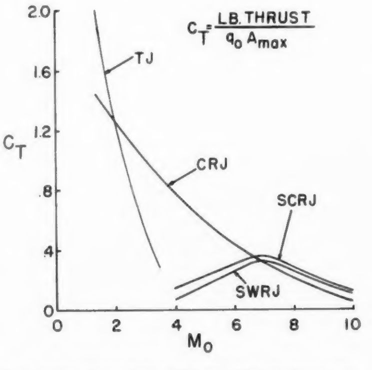
(CONTINUED FROM PAGE 39)

ramjet modifications will be touched on in a moment.

The supersonic combustion ramjet (SCRJ) has been treated analytically by Weber and MacKay in NASA TN 4386 of 1958. They suggest that a simple and promising version of this engine might look like that sketched in the first figure on page 39. For the Mach 7 flight, the wedge inlet of this SCRJ would compress the air flow (with the aid of the second oblique wave from the lip) to perhaps Mach 2.7, at which velocity it would enter the heat addition region. Maximum performance would be obtained by adding enough heat to reach the thermal choking Mach 1 condition at the heat addition exit (Station 4), but no more heat than this could be added without causing a normal shock in region 2–3.

For the SCRJ performance given in the figure on page 39, it has been assumed that the simple wedge inlet of optimum wedge angle is chosen for each speed (again, a "rubber engine"). The corresponding kinetic energy efficiency of this inlet is 0.97; the combustion efficiency is again 0.95; and the exhaust nozzle velocity coefficient is again 0.97. The major advantage of this hypothetical engine over the CRJ is that the normal shock loss is avoided and combustor inlet temperature is lower, so that the burned gas temperature is also lower and the departure from thermal equilibrium in the exhaust nozzle is accordingly smaller. Furthermore, the internal pressures are lower by a factor of 5 to 20 in region 2–3, varying upward to approximately the same maximum pressure at Station 4 as heat is added and the thermal choking condition is approached. Cooling requirement per square foot of engine internal surface between Stations 2 and 4 would also be smaller, but the SCRJ will probably be longer (larger heat transfer

Thrust Efficiency in Terms of Frontal Area



Conventional ramjets will have higher thrust coefficients than supersonic-combustion or standing-wave ramjets.

area) so that there may be no reduction in over-all requirement.

The biggest question facing this very interesting SCRJ engine cycle is whether fuel can be injected in either region 0–1 or 2–3 without disturbing the supersonic flow. If this can be accomplished, then mixing and reaction must also be accomplished in gases moving at 4000 to 9000 fps, all in the order of 1 millisec.

A third possible hypersonic engine cycle might be called the standing-wave ramjet (SWRJ), which is also illustrated in the first figure on page 39. In such an engine, fuel is added in a supersonic stream (region 1–2) ahead of either an oblique shock wave or a normal shock wave which is held stationary by the duct geometry and the heat release which occurs behind it (region 3–4). Dunlap, et al., (JET PROPULSION, 28, 451, 1958) and Roy (paper presented to International Council of Aero. Sciences, Madrid, Sept. 1959) have analyzed such engines. Gross (ARS JOURNAL, 29, 63, 1959) has stabilized normal waves with heat addition in a Mach 3 stream of hydrogen and air. The same problem of fuel addition in shock-free approach flow faces both the SWRJ and the SCRJ. The performance of the two engines would be identical for the case of equal diffusion between Stations 0 and 1 and equal heat addition causing normal shock in region 1–3 and $M = 1$ at Station 4. For lesser heat addition in the SCRJ, the latter will have the higher total pressure recovery and the higher efficiency. For the relative performance of the SWRJ, it is assumed that the "diffuser efficiency" is based on a shock loss equivalent to a Mach 3 normal shock, combustion efficiency is 0.95, and nozzle velocity coefficient is 0.97.

The figure on page 39 shows the known or expected engine efficiencies for various engines in supersonic and hypersonic speed ranges (arbitrarily designated as Mach 1 to 5, and greater than Mach 5, respectively). Engine efficiency is defined as follows:

$$\eta_e = \frac{3600\ V}{SFC\left(H + \frac{V^2}{2g}\right)} = \frac{I_f M a}{H + \frac{M^2 a^2}{2g}}$$

where V is flight speed in fps; SFC is specific fuel consumption in lb/hr/lb-thrust; H is heating value of the fuel in ft-lb/lb; g is gravitational acceleration; I_f is fuel specific impulse, lb-thrust/lb/sec; M is flight Mach number; and a is acoustic velocity at flight altitude. A constant-dynamic-pressure trajectory ($q_0 = 350$ psf) on the ICAO standard atmosphere is assumed in order to maintain reasonable engine pressure while flying high enough to mitigate "supersonic boom" problems.

Fuel-air ratio increases with flight speed for optimum I_f, but is arbitrarily limited to stoichiometric. Calculations by R. Breitwieser (NASA, to be published) suggest that the stoichiometric limitation imposed here should be removed for higher hypersonic speeds.

The middle diagram on page 39 shows that the conventional ramjet is more efficient than the turbojet at speeds above Mach 3.5 or thereabout. The supersonic combustion ramjet might in turn surpass the CRJ at approximately Mach 7, but for a Mach 7 transport, the CRJ would be the best choice.
The SWRJ is still poorer due to its shock loss.

Ramjet Superiority

The last figure, page 39, compares the same engines plus a rocket in terms of fuel specific impulse I_f. It can be seen that current ramjets have an order-of-magnitude superiority over rockets, and that the ramjet will remain superior in fuel economy to some Mach number near 10 or 11. The other engines hold the relative positions given in the figure on page 39.

On a thrust coefficient basis (or thrust per unit frontal area at equal q_0, where $q_0 = \gamma_0 p_0 M_0^2/2$) the rocket is, of course, far superior to the air-breathers. Among the air-breathers, as indicated in the figure on page 114, the CRJ is superior to the turbojet above Mach 2 and is far superior to the SCRJ and SWRJ for speeds to Mach 7. That is, for a given thrust level the CRJ is much smaller in frontal area and therefore has lower drag.

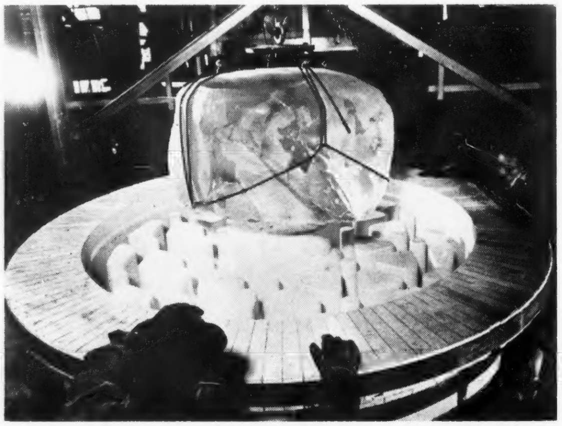
The kinetic energy efficiency obtained with the hypersonic diffuser will play a crucial part in the engine performance. While the efficiencies used in the preparation of the figure on page 39 are believed to be reasonable, the actual information available today on hypersonic inlets is still rather sparse, and better means for obtaining variable geometry with good operating characteristics at low weight penalty must be sought for both supersonic and hypersonic inlets. In proposed hypersonic commercial transports, the inlets for the Mach 3 to 4 turbojets or turboramjets, which would be used at the beginning and end of each trip, should operate efficiently from zero speed to Mach 3 or 4. The inlet for the hypersonic ramjet should then operate effectively from its take-over speed to Mach 7.

For a space launcher it is likely that the operating range for the ramjet would have to extend to speeds over Mach 7. For inlets operating over a wide range of hypersonic speeds, boundary layer buildup will be quite a problem, and boundary layer bleeding will not necessarily be a good solution, because recovery temperatures will be very high, so that the boundary layer air will be very hot. Leading edges will have to be rounded or blunted slightly for thermal protection, raising another problem in efficiency. Generally speaking, increased kinetic energy efficiency is gained only at the expense of weight (and/or drag) and increased sensitivity to variations in angle of attack or yaw, so that design compromises result.

Simpler Combustor Section

The combustor section will be much simpler than those used in present ramjets. The CRJ combustor in a hypersonic vehicle will be operating in the spontaneous ignition regime—vaporization rates and burning rates increase while ignition delays decrease, all being power functions of the combustor inlet temperature, which in turn is roughly proportional

Mirror Blank Cast for National Observatory



Corning Glass has cast the largest U.S. telescope mirror blank since the 200-in. disk for the Hale Observatory 25 years ago. Here, a chunk of low-expansion borosilicate glass is lowered onto the mold for the 84-in. blank The completed disk, former by a sagging process, in which separate chunks of glass placed on the mold are melted to shape, weighed 3500 lb. Molten glass was ladled into the mold for the 200-in. disk. The 84-in. mirror will be used in the larger of two telescopes for the Association of Universities for Research in Astronomy observatory being constructed, with the support of NSF, atop Kitt Peak near Tucson, Ariz.

to the square of flight Mach number for $M \geq 4$. It might further be noted, as E. Perchonok has discussed elsewhere in this issue, that these statements are qualified by the fact that at higher Mach numbers ($M \geq 6$) dissociation of molecules in the combustion chamber and recombination of atoms or molecular fragments in the exhaust nozzle will alter the axial temperature and velocity gradients considerably. The latter problem of dissociation and recombination rates in high temperature gas streams will receive increasing attention in laboratories and computing centers.

Ramjet Fuel

What of the ramjet fuel? For purely economic reasons, kerosene is expected to remain the "workhorse" fuel, even for speeds to Mach 10, in any recoverable or re-usable vehicle or aircraft. For expendable vehicles, more expensive fuels may be used for their higher heating value, greater density, or greater heat capacity or thermal stability (thus requiring less cooling or perhaps even serving as a coolant for metal parts).

The aerodynamic heating problem has been discussed extensively in the literature. It is one of the considerations in altitude-speed programs, as represented by the lower boundary of "the continuous flight corridor." By proper design for cooling by radiation from the airframe skin to the atmosphere, and by ingenious use of insulation and internal cooling, it should be practical to keep load-bearing members at acceptable temperatures. Heat transfer rates inside the combustor will be much greater than in current ramjet engines, and combinations of ceramic coatings and water or fuel cooling will be required to protect the internal surfaces. Molybdenum may find increased use in engines, but its expense and handling difficulties will have to be weighed against a nominal gain in tolerable surface temperatures as compared to currently available "super alloys."

Aerodynamic testing facilities now in use or under construction will be adequate for most of the hypersonic inlet work, but questions will still remain about the effects of hot surfaces on boundary layer thickness and flow separation under flight conditions. High temperature subsonic and supersonic facilities will be needed to investigate subsonic and supersonic mixing and combustion under realistic conditions, and high temperature hypersonic propulsion test facilities will be needed for scale testing of engines. A number of capacitance-type (pebble bed) heaters are now in existence throughout the country for supplying hypersonic tunnels of 6- to 20-in. diam with air at 2500 to 3500 F, and larger heaters of this type are planned or under construction. Electric arc heaters show promise for supplying higher temperatures.

Finally, the performance of a hypersonic vehicle, and thus the degree of economy or performance achieved with the engine, will also depend upon proper integration of the engine with the airframe. Not only will the over-all configuration drag be very important, but also maximum advantage will have to be taken of favorable wing-engine or body-engine pressure fields in order to increase engine thrust.

To conclude we believe the following to be true with regard to the potentialities and future of the ramjet engine:

1. Among air-breathing propulsion systems, the ramjet is the only engine which will be practical beyond Mach 4.

2. The current generation of ramjet engines has an order-of-magnitude advantage in fuel economy over current rocket engines, and the ramjet will retain its superiority well into the hypersonic regime.

3. For any flight within the earth's atmosphere, a ramjet-powered vehicle will have a tremendous advantage in weight, range, or payload over a rocket-powered vehicle.

4. It appears that ramjet-powered flight will be feasible at speeds approaching (and possibly exceeding) Mach 10.

5. It can be demonstrated that there are many valid reasons why a terrestrial or surface-to-surface vehicle should remain within the atmosphere (though most of the military implications cannot be discussed in this paper).

6. For putting a series of large payloads into space, a recoverable, maneuverable air-breathing launcher would have unique advantages in economy and reliability.

7. Of the ramjet modifications discussed, the conventional ramjet (or some slight variation of the configuration presented for it) appears more likely to find application than either the supersonic combustion or standing-wave type, mainly because of the difficulty of fuel injection and mixing in shock-free supersonic flow.

8. Though much R&D work is still needed, particularly in such areas as hypersonic inlets, materials and cooling techniques, and real-gas kinetics (the recombination problem), Mach 7 to 10 engines would be a reality by about 1965, and Mach 7 transports could be flying by 1970.

Government Contracts

(CONTINUED FROM PAGE 105)

ner for AICBM radar antenna, $49,991, **Chu Associates,** P.O. Box Box 387, Whitcomb Ave., Littleton, Mass.

Theoretical and experimental investigations on volumetric fixed aperture and radar scanning antennas, $69,757, **Chu Associates,** P.O. Box 387, Whitcomb Ave., Littleton, Mass.

Investigation of the properties of ultrapure nickel, $91,418, **Sylvania Electric Products, Inc.,** Bayside, N.Y.

Design and fabrication of sounding rockets, $95,953, **Aerojet-General,** 6352 N. Irwindale Ave., Azusa, Calif.

Research and development, $57,504, **Transitron Electronics Corp.,** 168–182 Albin St., Wakefield, Mass.

Research on a nonmagnetic stable platform for use in connection with magnetometer measurements from Aerobee-Hi sounding rockets, $105,993, **Aeronautical Div. of Minneapolis-Honeywell Regulator Co.,** 13350 U.S. Hwy. 19, St. Petersburg, Fla.

Research of meteor phenomena, upper atmospheric winds and turbulence, and chemiluminescence in upper atmosphere, $75,000, **Harvard College,** Cambridge, Mass.

Research of antenna behavior, $39,958, **Hycon Eastern, Inc.,** 75 Cambridge Parkway, Cambridge, Mass.

Research on the detection of far infrared radiation, $39,071, **Ramo Wooldridge,** 5730 Arbor Vitae St., Los Angeles, Calif.

Research on experimental determinations of ionospheric characteristics using satellite radio transmission, $42,998, **Boston College,** Chestnut Hill, Mass.

Study of fundamental physics of ferromagnetic and ferroelectric materials, $100,000, **Harvard College,** Cambridge, Mass.

Investigation of microwave properties of plasmas, $95,000, **Stanford Univ.,** Stanford, Calif.

Study of the ionospheric phenomenon of spread-F, $34,905, **Cornell Aeronautical Lab.,** 4455 Genesee St., Buffalo, N.Y.

Research study of steerable antenna techniques for airborne ferret reconnaissance, $40,584, **Electronic Communications, Inc.,** Research Div., 1830 York Rd., Timonium, Md.

Development, production, and adaptation of one balloon biaxial pointing control to provide a reference line for a sky sweeping optical surveillance unit, $39,-039, **Hi-Altitude Instrument Co.,** 2355 Ames St., Denver, Colo.

Hq, AF Office of Scientific Research, ARDC, Washington 25, D.C.

Continuation of research on review and analysis of aeronautical research information, $25,050, **IAS,** 2 E. 64 St., New York 21, N.Y.

Continuation of research on rational scaling procedures for liquid fuel rocket engines, $42,209, **Sundstrand Turbo Div. of Sundstrand Machine Tool Co.,** 10445 Glenoads Blvd., Pacoima, Calif.

Continuation of research on nuclear reaction studies, $349,475, **Washington Univ.,** St. Louis, Mo.

Research on ultra-energy fuels for rocket propulsion, $31,777, **Aerojet-General**, Azusa, Calif.

Continuation of research of aerodynamic noise, $39,772, **Gruen Applied Science Labs.**, Hempstead, N.Y.

Continuation of nuclear emulsion research with high energy accelerators, $84,044, **Univ. of Chicago**, Chicago 37, Ill.

Investigation of upper atmosphere powerplants, $78,975, **Aerojet-General**, Azusa, Calif.

Investigation of the mechanism of combustion of composite solid propellants, $91,526, **Aerojet-General**, Azusa, Calif.

Study of high precision geocentric and interplanetary orbits, $31,515, **Univ. of California**, Berkeley 4, Calif.

Continuation of studies of kinetics of solid phase reactions, $38,320, **Aerojet-General**, Azusa, Calif.

Continuation of experimental study of transport phenomena in metals, $53,042, **Carnegie Institute of Technology**, Pittsburgh 13, Pa.

Continuation of research on spectroscopic studies of high temperature gases, $70,079, **Cornell Aeronautical Lab.**, 4445 Genessee St., Buffalo 21, N.Y.

Continuation of research on hypersonic viscous flow phenomena, $30,000, **Rensselaer Polytechnic Institute**, Troy, N.Y.

Continuation of research on the theory of scattering, $34,000, **Univ. of Maryland**, College Park, Md.

Continuation of work on low-temperature investigation of the interaction between ultrasonic waves and electrons in metals, $73,810, **Brown Univ.**, Providence, R.I.

Continuation of research on analytical and experimental study of high frequency oscillatory combustion and of scaling of rocket motors, $142,500, **Polytechnic Institute of Brooklyn**, 99 Livingston St., Brooklyn 1, N.Y.

Continuation of investigation of positive ion surface emitters, $89,376, **Aerojet-General**, Azusa, Calif.

Continuation of research on flow problems at high Mach numbers, $90,000, **Polytechnic Institute of Brooklyn**, 333 Jay St., Brooklyn 1, N.Y.

ARMY

Boston Ordnance Dist., Army Base, Boston 10, Mass.

R&D devices for use in Nike Hercules design and manufacture, $63,412, **Raymond Engineering Lab.**, Middletown, Conn.

Cleveland Ordnance Dist., 1367 E. Sixth St., Cleveland 14, Ohio.

Design, develop, fabricate, install, and test one water jet propulsion device in a truck, amphibious, $74,163, **Hanley Hydrojet, Inc.**, Prospect, Ohio.

U.S. Army Ordnance Dist., Los Angeles, 55 S. Grand Ave., Pasadena, Calif.

Target drones R&D, $596,369, **Radioplane Co.**, 8000 Woodley Ave., Van Nuys, Calif.

Telemetering system, $62,324, **Thomp-**

son **Ramo Wooldridge,** 5500 West El Segundo Ave., Los Angeles, Calif.

R&D, $1,500,000, **CalTech,** 1201 E. California St., Pasadena, Calif.

Telemetry sets, $303,458, **Motorola,** 8201 E. McDowell Rd., Phoenix, Ariz.

Rocket engines, $535,000, **North American Aviation,** 6633 Canoga Ave., Canoga Park, Calif.

Design and development, $30,000, **North American Aviation,** Rocketdyne Div., 6633 Canoga Ave., Canoga Park, Calif.

Overhaul and modify gyroscopes, $631,982, **Whittaker Gyro Div. of Telecomputing Corp.,** Van Nuys, Calif.

Fuzes, $378,900, **Harvey Aluminum,** Torrance, Calif.

Instrumentation and control system, $38,846, **Aerojet-General,** Azusa, Calif.

Telemetry and instrumentation packages, $53,361, **Gilfillan Brothers,** Los Angeles, Calif.

Research and development for developmental engineering, $264,680, **Harvey Aluminum,** Torrance, Calif.

Testers, $104,205, **Telecomputing Corp.,** N. Hollywood, Calif.

R&D, $98,605, **Rheem Mfg.,** Downey, Calif.

Measurements and accumulation of missile data, $45,468, **Aerojet-General,** Azusa, Calif.

Development of missile checkout equipment, $1,887,027, **Nortronics Div. of Northrop Aircraft,** Anaheim, Calif.

Technical assistance, $108,523, **Associated Aero Science Labs,** Hawthorne, Calif.

U.S. Army Signal Supply Agency, 225 S. 18th St., Philadelphia 3, Pa.

Experimental work for 4 months to study propagation phenomena related to signals transmitted from satellites and space vehicles, $61,576, **RCA Service Co.,** Camden, N.J.

Competitive test and evaluation between SD-2 and a competitor's surveillance drone, $60,412, **Rheem Mfg. Aircraft Div.,** Downey, Calif.

Meteorological balloon, $53,803, **W. R. Grace & Co.,** Dewey & Almy Div., Cambridge, Mass.

NAVY

Dept. of the Navy, BuAer, Washington 25, D.C.

Study of the adequacy of the range instrumentation equipment at the Pacific Missile Range, $492,878, **Aeronutronic Systems,** Glendale, Calif.

Study to analyze and evaluate the developed missile facility package, $31,875, **Stanford Research Institute,** Menlo Park, Calif.

U.S. Naval Training Device Center, Pt. Washington, N.Y.

Research study on weightlessness, training requirements, and solutions. $32,465, **Operations Research, Inc.,** Silver Spring, Md.

U.S. Navy Purchasng Office, 1206 S. Santee St., Los Angeles 15, Calif.

Telemetering equipment, $74,842, **Hewlett-Packard Co.,** 275 Page Mill Rd., Palo Alto, Calif.

Missile Market

(CONTINUED FROM PAGE 50)

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CAL Expanding Microwave Research

Supported by a recently awarded $1.3 million Army Ordnance contract, Cornell Aeronautical Lab will expand its research into microwave radar, aiming at a peak power of 50 million watts at a variety of pulse lengths and rates and at an average power up to 50 thousand watts. Last year CAL demonstrated transmission at 21 million watts of peak power with its laboratory equipment. Much of CAL's contract covers the purchase of new equipment. The research has one focus in missile defense systems and another in long-range space communication, for example, by investigating noise level owing to echoes from the ionosphere and possibly from auroras, cosmic dust, and other atmospheric disturbances.

UCLA Offers Course In Vehicle Systems

The Engineering Extension of the Univ. of California at Los Angeles is offering a course in "Ballistic and Space Vehicle Systems" this semester. Coordinated by Howard Seifert of Space Technology Labs, ARS national vice-president, the course, which got underway March 3, will present a number of lecturers covering such subjects as propulsion, design, flight dynamics, structures, performance, control, and guidance from the standpoint of the over-all system.

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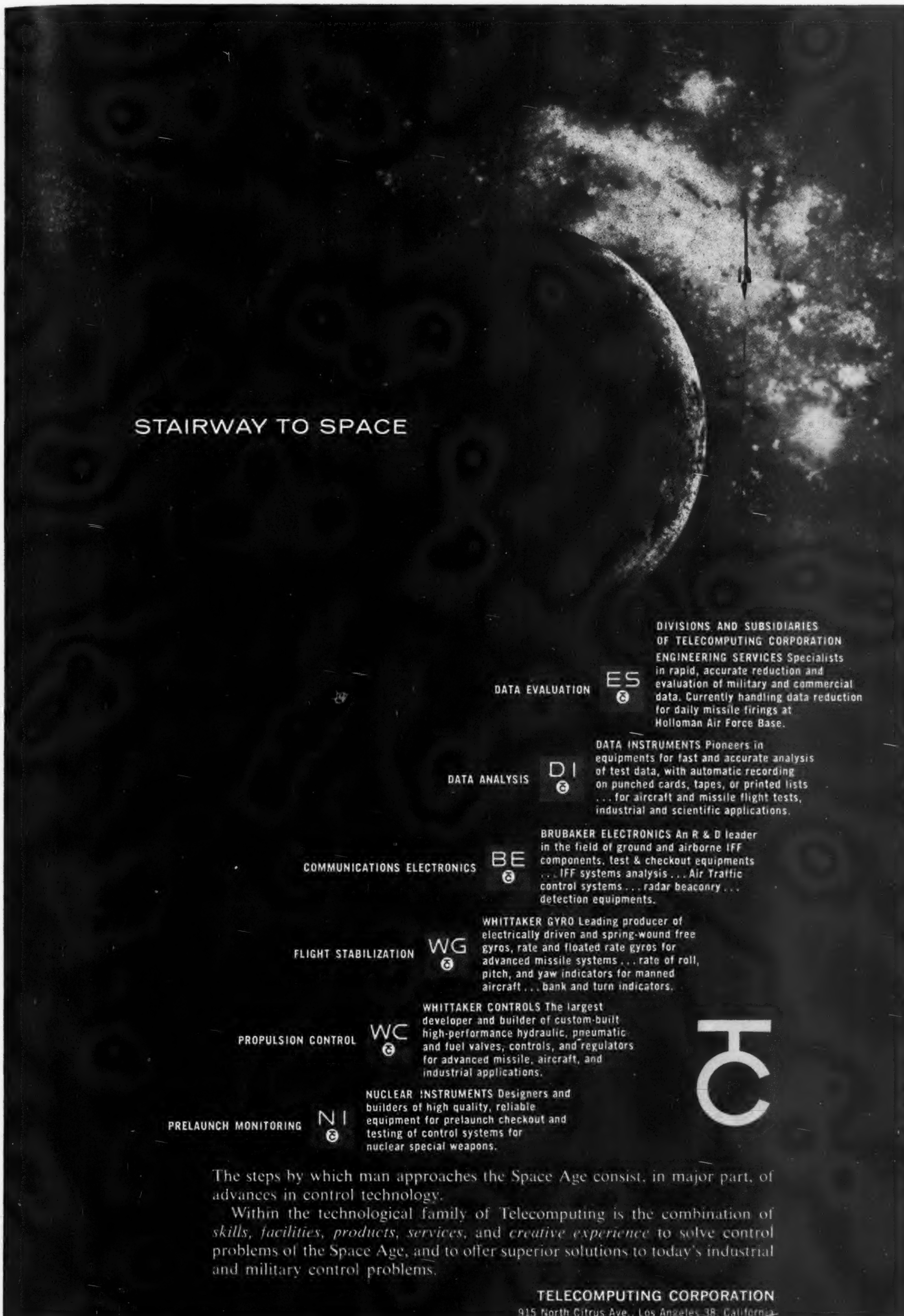
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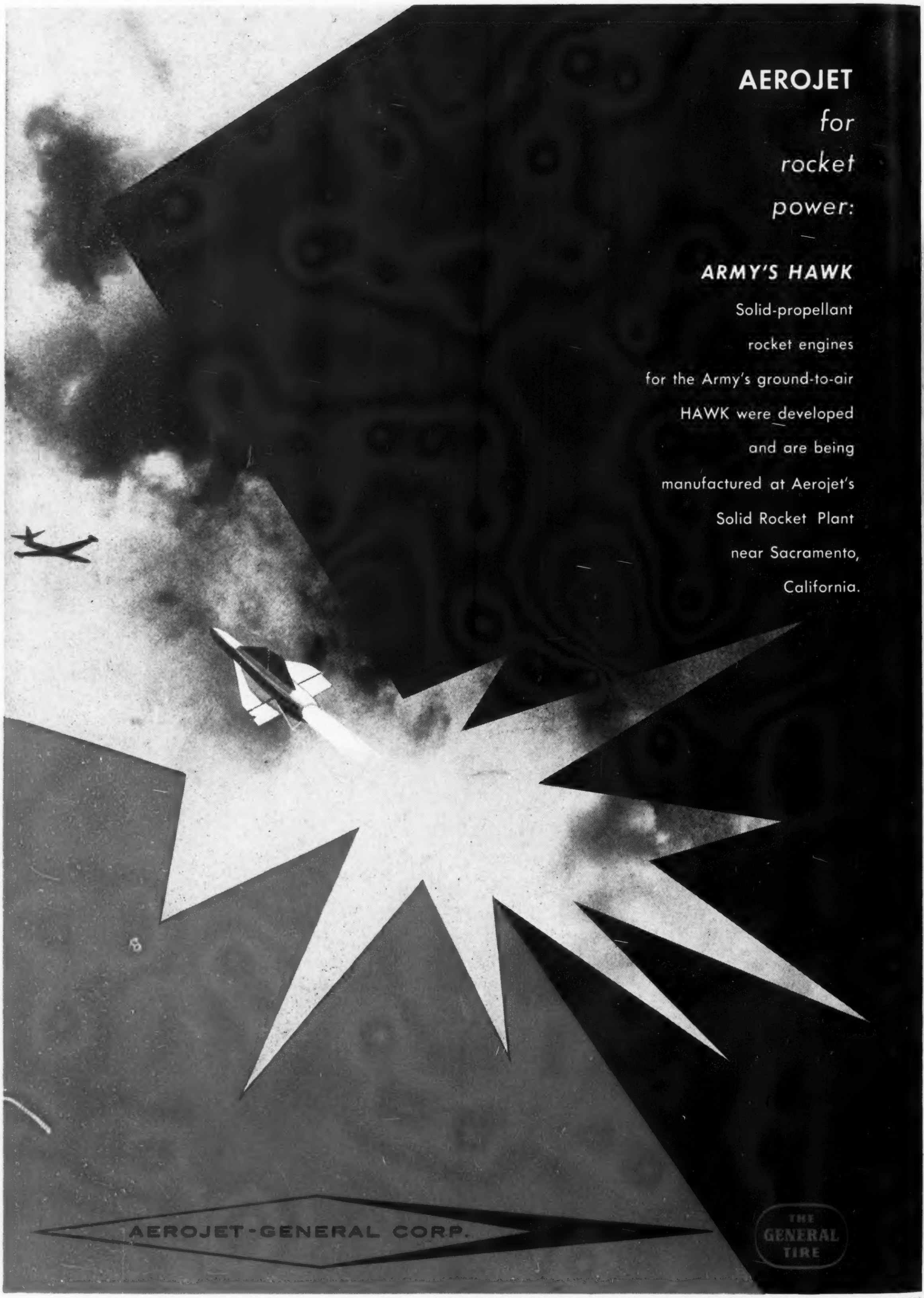
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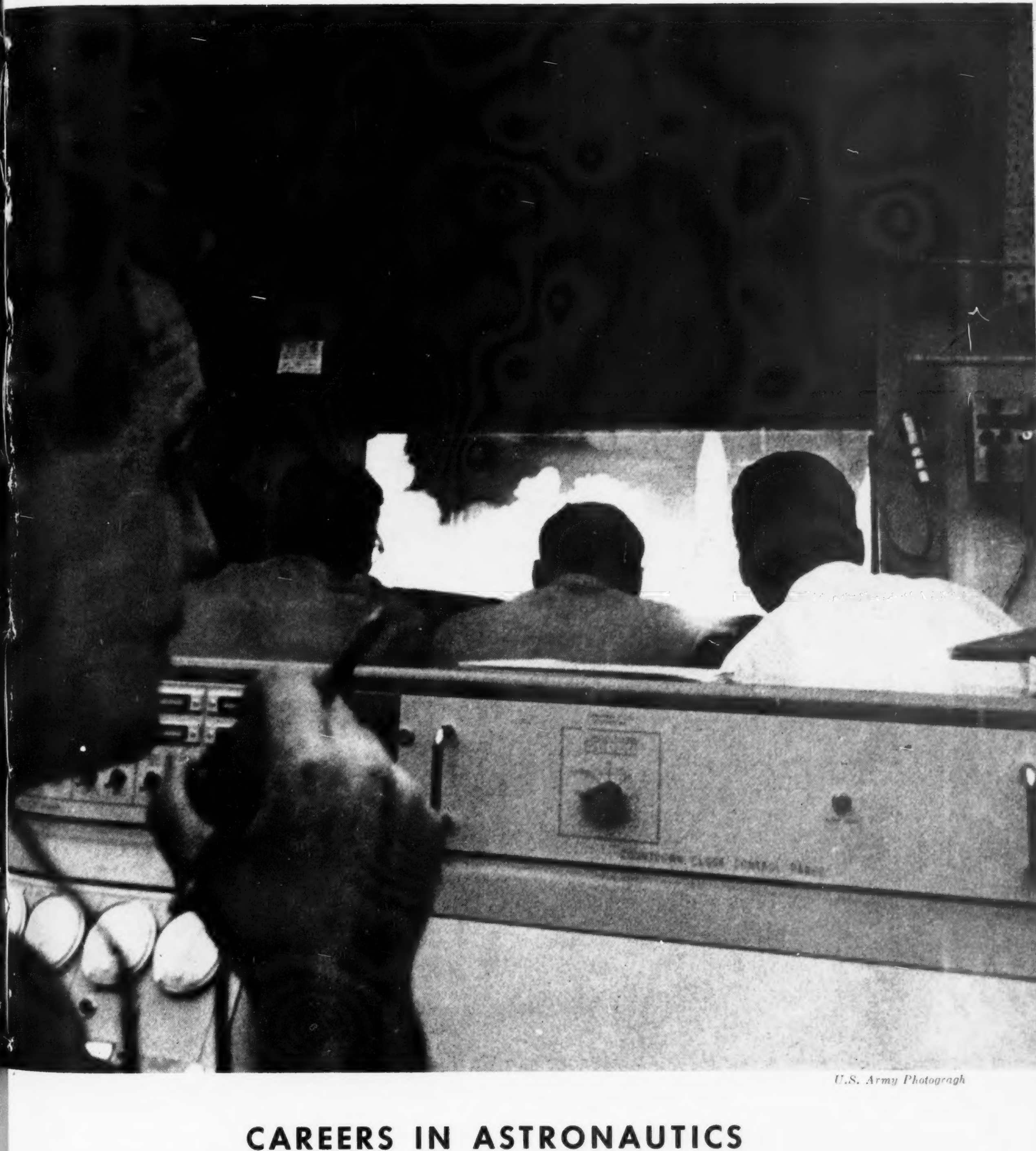

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Careers in Astronautics

FEATURES

CAREER OPPORTUNITIES

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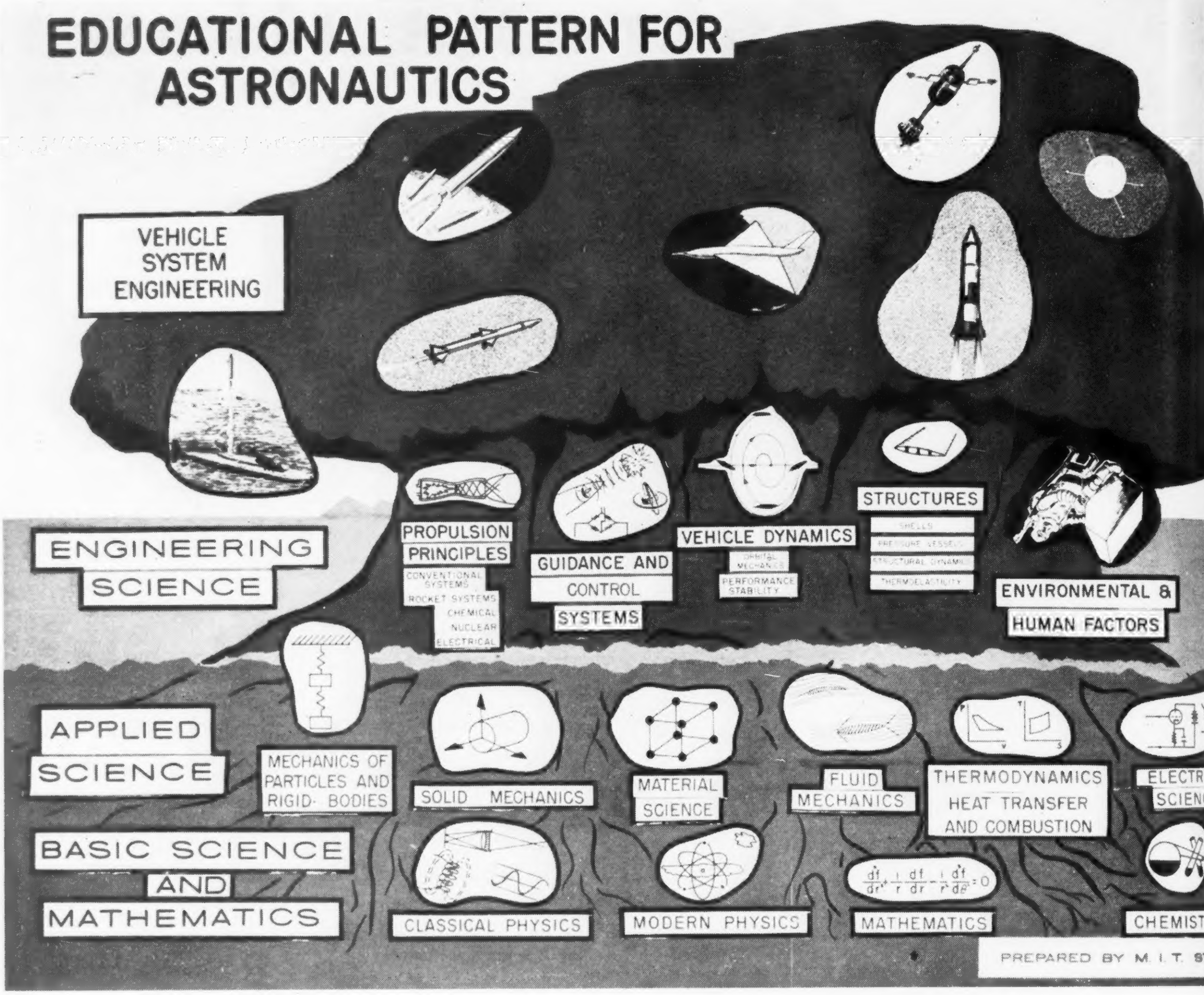

Educational opportunities in astronautics

By Paul E. Sandorff

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CHAIRMAN, ARS EDUCATION COMMITTEE

Do U.S. universities teach Astronautics?

Definitely yes.

This is, in effect, the reply the Education Committee of the American Rocket Society received last month, after sending a survey questionnaire to all engineering colleges and universities in the United States.

At present, however, the course of study followed by the student may not be called Astronautics, and his degree may be granted with specification in some previously established profession. Also, a schedule of courses integrated to provide the particular combination of training he desires may be difficult to arrange, and usually will require graduate study. But for the most part, education in the Astronautical sciences and professional engineering subjects is available to a considerable extent, particularly in the larger engineering universities.

Moreover, several universities already treat Astronautics as a field of education in its own right. This survey, actually the second conducted by the Education Committee, reveals considerable upswing of academic activity in Astronautics over a year ago. Several universities have doubled the scope of their treatment of this field

and several have come to recognize Astronautics by departmental name, by course identification and by degree. Many are in the process of re-arranging their curricula and adding new topics to provide an orderly treatment of the new field.

Modifications Necessary

One of the difficulties besetting students and staff alike is that many subjects germane to Astronautics are already presented only as advanced studies in some specialized field, and require considerable preparation in prerequisite courses. For example, physics of the upper atmosphere may be available only to a graduate in meteorology; telemetering and radio guidance only to a graduate in electrical engineering, etc. Modifications must be made to serve the broader interests of the Astronautics student without becoming shallow in treatment and sacrificing strength and stature of the presentation. This dilemma is being met, and many students who enter college next fall may find that, by the time they are ready for specialization in professional studies, a well-developed program leading to a degree in Astronautics will be available.

Defining Astronautics

What is Astronautics? This is one of the first questions the Education Committee found itself faced with.

TECHNICAL DISCIPLINES IN ASTRONAUTICS

(Socio-humanities not included)

A. Fundamental Sciences

1. *Mathematics:* Differential and integral calculus; analytic geometry; partial differentiation; differential equations; Laplace transform; Fourier series; boundary value problems.

2. *Classical Physics:* Newtonian mechanics; statics and hydrostatics; rigid body dynamics; oscillations and waves; heat and kinetic theory; electricity and magnetism; optics, atomic physics.

3. *Basic Chemistry:* Atomic structure; mass and energy relationships; rate and equilibrium of chemical reactions; ionic chemistry; acid-base systems; crystals and molecules.

B. Applied Sciences

1. *Statics and Dynamics:* Forces and moments, stability and instability; kinematics of particles; work and energy; impulse and momentum; rigid-body dynamics; linear oscillatory systems; free and forced vibrations including damping.

2. *Solid Mechanics and Physics of Materials:* Force transmission; stress-strain relations; stress distribution and deformation; beam theory; shear and torsion; buckling and instability; material structure; material failure; plasticity; stress-strain-temperature-time relations; stress concentration, brittle failure, and fatigue.

3. *Electrical Science:* Principles of electrical circuits; components and systems for power, control, and instrumentation; theory and performance of electrical components, circuits, and systems.

4. *Fluid Mechanics and Gasdynamics:* Dynamics and thermodynamics of real and perfect fluids; one-dimensional flow; incompressible and compressible flow, viscous and turbulent flow; lift, drag, and boundary layer effects.

5. *Thermodynamics:* Thermodynamic laws; properties of liquids, vapors, and gases; heat transmission; gas and vapor cycles.

C. Professional Engineering Subjects

1. *Mechanics of Orbits and Trajectories:* Celestial mechanics; orbits and perturbations; space flight trajectories; exterior ballistics of rockets; powered flight trajectories; optimization techniques.

2. *Propulsion for Rockets, Missiles, and Space Vehicles:* Fundamentals of rocket propulsion; solid and liquid chemical rocket engines; rocket components and accessory design and performance; nuclear, plasma, ion, and other systems.

3. *Rocket and Space Vehicle Structures and Materials:* Analysis and design of shells and pressure vessels; elastic and plastic response to dynamic loads; applied thermoelasticity and aerothermoelasticity; basic loads and materials for missiles and space vehicles.

4. *Guidance, Navigation, and Control for Missiles and Spacecraft:* Inertial, celestial, and electronic navigation techniques; missile guidance systems; control system design for missile and/or space vehicle.

5. *Vehicle Design:* Rocket vehicle performance; missile and/or space vehicle design; practice in system design combining propulsion, mechanics, aerodynamics, structures, guidance, and control for missiles, re-entry vehicle, space vehicle, etc.

D. Professional Sciences

1. *Communications:* Radar systems; ultra-high frequency techniques; information theory; microwave circuits; electromagnetic radiation theory and antenna design; telemetering; pulse circuit analysis.

2. *Astronomy:* Planetology; study of the sun, asteroids, comets, and meteors; astrophysics; physical astronomy.

3. *Physics of the Upper Atmosphere:* Composition, properties, meteorology of the upper atmosphere; tools of upper atmosphere research.

4. *Hypersonic and Rarefied-Gas Dynamics:* Superaerodynamics; free molecule flow; slip flow; piston theory; boundary layer and heat transfer effects for rarefied gases and gases at high temperature; plasma physics; magnetohydrodynamics.

5. *Space Medicine:* Physiological and psychological aspects of environment of upper atmosphere and space; artificial environments and environmental control.

E. Related Advanced Science and Engineering

1. *Advanced Mathematics:* Probability and operations analysis; statistical theory; advanced calculus; variational calculus; field theory; machine analysis and digital techniques.

2. *Aeronautical Sciences:* Three-dimensional flow; wing theory; classical performance, stability, and control; aircraft propulsion; aeroelasticity.

3. *Modern Physics, Solid State Physics:* Quantum theory of matter; quantum mechanics; theory of molecular structure; interaction of matter with electric and magnetic fields; insulators, semiconductors, metals, and molecular compounds; relativistic mechanics and dynamics.

4. *Nuclear Technology:* Nuclear structure; nuclear reactions; reactor theory and design; shielding; reactor control.

5. *Physical Chemistry:* Composition and physical states of matter; chemical thermodynamics; kinetic theory of gases; properties of solutions; kinetics of chemical reactions; surface and colloid chemistry; atomic and molecular spectra; electronic structure of molecules; theory of combustion; transport phenomena.

6. *Meteorology and Geophysics:* Physical meteorology; planetary atmospheric dynamics; geochemistry; geophysics; geodynamics; geodesy.

7. *Metallurgy and Materials:* Metallurgical science; advanced materials science; physics of strength and plasticity.

8. *Automatic Control and Servomechanism Theory:* Linear representations of physical systems and analysis of their performance; stability criteria, transient response, frequency response; feedback loops; performance functions by Laplace transforms; analytical, graphical, and analog methods; advanced servosystem analysis and design.

9. *Structures:* Advanced mathematical theory of elasticity and plasticity; advanced shell theory, theory of shallow shells; large deflection theory; methods of optimum design; experimental stress analysis.

Their answer is given by the impressive compilation of technical disciplines described in the table on the preceding page.

The basic and applied sciences, Parts A and B of this table, are necessary fundamentals for firm training in any field of engineering. These studies are usually completed in the first two or three years of a university education.

In the third and fourth years of undergraduate study, if the usual pattern is followed, the engineering student develops his professional subjects in breadth. This means familiarity with and some degree of competence in the professional engineering subjects and in the professional sciences, Parts C and D of the table.

Also, in the latter years of undergraduate work, and in his postgraduate studies if he elects such a program, the student develops strength in some area or areas of specialization. These special interests may be any of the professional sciences or engineering subjects, or it may be one of the closely related advanced science or engineering topics described in Part E of the table.

Maturation of Students

The maturation of the Astronautics student may be visualized by means of the "tree of engineering knowledge" on page 2, in which the fundamental and applied sciences represent the roots of the tree and the professional engineering sciences the many-stemmed trunk, with the fruits being concerned with full-blown vehicle systems.

Not included in this summary of technical disciplines are the socio-humanities: Language and self-expression, history, philosophy, literature, economics, political science, psychology, and the arts. Educators recognize the importance of training in these fields to the development of engineers and scientists who will assume responsible positions in society. Consequently, despite the pressure of ever-expanding technologies, a certain amount of humanities studies forms a required part of the curriculum of every accredited engineering school.

To make an assessment of the educational opportunities available, educational institutions were requested to use the table on page 3 as a method of classification, and to report on the number of courses presented and the opportunities for research under each category. The replies are summarized in the table shown below. (Only

DETAILED DATA ON TECHNICAL CURRICULA IN FIELD OF ASTRONAUTICS

Numbers in the table below (e.g., 1, 4, etc.) indicate the total number of different courses of study presented in the respective topic area, classified according to the table on page 3. The letter x indicates one or more courses presented, actual number not identified. The letter e indicates extensive treatment, with more than six different courses presented.

	Topic Areas in Which Courses Are Presented			
	C 12345	D 12345	E 123456789	Opportunity for Research Work
Alabama				
Ala. Poly. Inst.	xxxxx	xxxx	xxxxxxxxx	C3, 4; D1; E1, 2, 3, 4, 5, 8, 9
Univ. of Alabama	1x x	111x	eee1x1e1x	C3; E1, 2, 3, 7, 9
Arizona				
Univ. of Arizona	42e22	eex42	eeee4ee4e	C2, 3; D1; E2, 4, 9
California				
California Inst. of Tech.	3e21	4e 2	e3e3e ee3	C, D, E extensive
California State Poly. Tech.		x	xx x	
Northrop Aero. Inst.	114	1	1123	
Stanford Univ.	1151	e 15	eee3e1e3e	C3, 4; D1, 4; E (all)
Univ. of California	3233	eeee	eeeeeeeee	C, D, E extensive
Univ. of Cal. at Los Angeles	42xx1	33122	exx221 ee	C1, 2, 3, 4; D1, 4; E1, 5, 6, 7, 8, 9
Univ. of Santa Clara	xx	x x	x x x x	none
Univ. of So. California	13ee1	exxex	eeexe xee	C2, 3, 4; D1, 4, 5; E1, 3, 5, 7, 8, 9
Colorado				
Colorado State Univ.	1		2 121 212	
Univ. of Colorado	13312	1e1	2ee12e221	C2, 3, 4, 5; D1, 2, 3, 4, 5; E1, 2, 3, 5, 6, 7, 8, 9
Univ. of Denver	1	21	4 324 432	D1, 3; E1, 5, 7, 8
USAF Academy	x1 1x	1 x1	11 11	
Connecticut				
Yale Univ.	12ex	ee 1	e2e2e eee	C, D, E
Univ. of Bridgeport	1	1 1	21 12	
Univ. of Connecticut	11	x	x1 x x1x	C, D, E
Trinity College	2		4 5 e	E1, 5
Delaware				
Univ. of Delaware	x	x x	x x2x 13x	C2, 3; E1, 3, 4, 5, 7, 8
Florida				
Univ. of Florida	xxxxx	xxxxx	xxxxxxxxx	C2, 3, 4; D1, 4, 5; E2, 3, 4, 5, 8, 9
Univ. of Miami		x	xxx x x	None
Georgia				
Georgia Inst. of Tech.	312	e 1	eee4e11 1	C1, 3; D1, 4; E1, 2, 3, 4, 5
Idaho				
Univ. of Idaho	111	1111	x2xxxxxxx	C2; D1; E1, 4, 5
Illinois				
Bradley Univ.	2	31	2 222 2	
Illinois Inst. of Tech.	5 1	3	64916 115	D1; E1, 3, 5, 9
Northwestern	13461	76 4	e6e576ee7	C, D, E extensive
Univ. of Illinois	33e11	ee 31	eeeee2e2e	C, D, E extensive
Indiana				
Notre Dame	1	1	exx2e exx	C, D, E
Purdue Univ.	26e21	e2 4	eeeee23ee	C2, 3; D1, 4; E1, 2, 3, 4, 5, 7, 8, 9

	Topic Areas in Which Courses Are Presented			
	C	D	E	Opportunity for Research Work
	12345	12345	123456789	
Iowa				
Iowa State College	33213	exxxx	eeeeexeee	C, D, E extensive
Univ. of Iowa	1 2	4ex	ee235x 1e	
Kansas				
Kansas State College	111	3 11	ee ee 23	C2; E2, 3, 4, 5, 8
Univ. of Kansas	xxx11	xx 1	eeexexeee	C, D, E
Univ. of Wichita		x	xxx x xxx	
Kentucky				
Univ. of Kentucky		e22	e2eee e5	D1, 3, 5; E3, 4, 5, 6, 7, 8
Louisiana				
Louisiana Poly. Inst.		11	2	None
Louisiana State Univ.	1 1	31	323242222	C3; D1, 2; E1, 3, 5, 8, 9
Southwestern Louisiana Inst.	21 1	2 2	611122231	None
Tulane Univ.		11 1	1 111 11	
Maine				
Univ. of Maine		x	x xxx xx	Yes (unspecified)
Maryland				
Johns Hopkins Univ.	e	x 1x	eeexexxxe	C, D, E extensive
Univ. of Maryland	1x1 1	x113	xexxx1xxx	C1; D2, 3, 4; E1, 2, 3
Massachusetts				
Harvard Univ.	xx	xexxx	exe1exexx	C1; D1, 2, 3, 4; E all
Lowell Tech. Inst.	2 2	3	e e56 x3x	D1, 3; E3, 4, 5
Mass. Inst. of Tech.	32253	e126	eeeeeeeee	C, D, E extensive
Univ. of Massachusetts	11	21	112241212	D1; E5, 9
Worcester Poly. Inst.	11	2	93434 536	E
Michigan				
Michigan State Univ.	1121	71 1	717181633	D1; E1, 8, 9
Univ. of Detroit	1 1	1	1111 1	None
Univ. of Michigan	x1x1x	11xx	xexxxxxxe	C, D, E extensive
Minnesota				
Univ. of Minnesota	22e21	e3431	eee3e233e	C, D, E extensive
Mississippi				
Mississippi State Univ.		2	5 1 3 3	D1; E8
Univ. of Mississippi		11	4 224 112	E1, 9
Missouri				
Missouri School of Mines	x	x	x eeeeexe	C3; D1; E3, 4, 5, 6, 7, 8, 9
St. Louis Univ.	1x x	x 2	3xxxxe 4x	D3; E3, 4, 6, 8
Washington Univ. of St. Louis		x	e x x xex	
Montana				
Montana State College	3	e1	4 32e 51	D1; E5, 8
New Hampshire				
Univ. of New Hampshire		41	e eee3322	D1, E
New Jersey				
Princeton Univ.	xx	x x	xxx x x	C2; D4; E2
Rutgers Univ.		x	x xxx xxx	
Stevens Inst. of Tech.	xx x	e x	eeexx exx	Yes (not specified)
New Mexico				
New Mexico Coll. of A. and M.A.	11	2 1	6111113	Some
Univ. of New Mexico	x x	xxx	xxxxxxxxx	D, E
New York				
City Coll. of New York	x 24	e22x	e24e6e45e	None
Clarkson Coll. of Tech.	x	x	x xxx xxx	Yes (not specified)
Cornell Univ.	214 1	ee31	ee56e e5e	Yes
Manhattan College	x	x xx	x xxx x x	
New York Univ.	134	e 2	e2443ee22	C, D, E extensive
Polytechnic Inst. of Brooklyn	145e1	e 15	e7e6e ee7	C, D, E extensive
Rensselaer Poly. Inst.	1xx1	xx1x1	xexexxexx	C2; D3, 4; E2, 3, 4, 5, 7, 9
Syracuse Univ.	xx	x	xxxxxxxxx	C3; D1; E2, 3, 4, 5, 7, 8, 9
Univ. of Buffalo	xx	xx x	xxxxx xx	C3; D1, 4; E1, 2, 3, 8, 9
Univ. of Rochester	xx	55xxx	e ex4xxex	C3; D1, 5; E1, 3, 4, 5, 7, 8
Union College	xx	xx	6x32xxxxx	Yes, not specified
North Carolina				
North Carolina State Coll.	12112	5111	68977 687	C1; D1; E1, 2, 3, 4, 5, 7, 8, 9
North Dakota				
Univ. of North Dakota		x	xxxxxxx x	D1; E1, 3, 4, 5, 9
Ohio				
AF Inst. of Tech.	xxxxx	x xxx	xexxx xex	C, D, E extensive
Case Inst. of Tech.	3221	6e 1	eee6e ee5	C, D, E extensive
Fenn College		1	1 111 1	Yes (not specified)
Ohio Northern Univ.		xx	x xxx x	None
Ohio Univ.		33	2 23e 11	
Ohio State Univ.	35ex1	ee14x	eee7eeeee	C, D, E extensive
Univ. of Akron	x	11	1 11 11	No
Univ. of Cincinnati	xxx x	xx x	exxxxxxxx	C1, 2, 5; D2, 4, 5; E2, 4, 9
Univ. of Toledo	xx	xxx	xxxxxxxxx	Increasing
Western Reserve Univ.		3	1 444 1	Yes

(CHART CONTINUED ON NEXT PAGE)

	Topic Areas in Which Courses Are Presented			
	C	D	E	Opportunity for Research Work
	12345	12345	123456789	
Oklahoma				
Oklahoma State Univ.	xx	x x	xxxxx xx	C2, 3; D4; E1, 2, 3, 4, 5, 8, 9
Univ. of Oklahoma	11	x x	e e e1	
Oregon				
Oregon State College	xx	x x	xxxxxxxxx	Some
Pennsylvania				
Carnegie Inst. of Tech.	1 2	3 1	e1e1x e23	C1, 3; D1, 4; E1, 2, 3, 5, 7, 8, 9
Drexel Inst. of Tech.	121	e	e43ee 3e2	D1; E3, 4, 5
Lehigh Univ.		4 1	e 443 26	C3; D1; E3, 4, 5, 7, 8, 9
Penn. Military College	1	1	1	
Penn. State Univ.	74e42	5432x	eeeeeee5e	C, D, E extensive
Univ. of Pennsylvania	xxx	ee xx	e3e4e eee	C2,3; D1, 2, 4, 5; E extensive
Univ. of Pittsburgh	xx	x	xxxxx xxx	C3; D3; E1, 2, 3, 4, 9
Villanova Univ.	xx	xx x	e122x 22x	C; E
Rhode Island				
Brown Univ.	1x	93 2	97314 429	C2, 3; D1, 2, 4; E1, 2, 3, 7, 8, 9
Univ. of Rhode Island	1	21	52212 111	D3; E6, 7
South Carolina				
Clemson College	1	41	e2e2e 321	E
South Dakota				
South Dakota State College		x1	xxx 21	Yes (not specified)
Texas				
A. and M. Coll. of Texas	3 x	xxx	4344eex31	D1, 2, 3; E1, 2, 3, 4, 5, 8
Lamar State Coll. of Tech.	x1		x1x1x 12	Limited
Rice Institute	111	1 1	e2e2x xxx	C2, 3; D4; E1, 2, 3, 4
Southern Methodist Univ.	1211	2 1	2e 722 57	D4; E2, 4, 8, 9
Univ. of Houston	1	4	e1414 112	C3; D1; E1, 3, 5, 8
Univ. of Texas	2122	3411	eeeeeee2e	C,D,E,
Utah				
Utah State Univ.		13	3458	C1
Vermont				
Univ. of Vermont	x	x x	x xxx xxx	D1; E5, 7
Virginia				
Virginia Poly. Inst.	2x	62 2	eeeee3e3e	D4; E2, 3, 4, 9
Washington				
Seattle Univ.	x	x	xxxxx xx	C3; E5, 7, 8, 9
State Coll. of Washington	xx	xxx	1 111 11	Some
Univ. of Washington	11x	e321	eee5eee5e	C, D, E extensive
West Virginia				
West Virginia Univ.	xx	xxx	xxxxxxxxx	C3; D1; E extensive
Wisconsin				
Marquette Univ.	2	xx x	exe4e1e3x	D1, 5; E1, 3, 4, 8, 9
Univ. of Wisconsin	1xxx	exxx	exeeeeexx	C2, 3; D, E extensive
Washington, D.C.				
Catholic Univ. of America	xx 21	1	xxxxx x	Yes (unspecified)
George Washington Univ.	1	4	5 2 3 22	D5, 8, 9
CANADA				
British Columbia				
Univ. of British Columbia		x	xxxxxxxxx	D1; E3, 5, 6, 7, 8
Quebec				
Ecole Polytechnique, Montreal	1	1	1 1121x11	C3; D5, 7, 8, 9
New Brunswick				
Univ. of New Brunswick		4	31111 121	E1, 5, 8, 9

returns which indicate some activity in the professional subjects, Parts A and B, have been included in this summary.)

No attempt was made to rate the various schools responding to the questionnaire on the excellence of their academic programs, or on the capabilities of the faculty presenting the programs. Indeed, this was not the object of the survey. Furthermore, it is assumed that all the schools which grant engineering degrees provide suitable coverage of the fundamental and applied sciences described as Parts A and B of the table on page 3. The returns therefore show where courses of instruction in the various categories are available, and approximately to what depth. The listing in the table on page 4 is alphabetical, by states.

Table Is Qualitative Guide

Some ambiguity in course descriptions is unavoidable, and the prospective astronautics student is advised to use the table on page 4 only as a qualitative guide. Course schedules are issued by all universities which describe the subject matter in some detail. For additional information regarding specific courses and programs, questions should be directed to the office of the Dean of Admissions or Dean of Engineering of a particular university.

It is, of course, an exceptional school that would be able to present thorough coverage of all aspects of the enormously broad field of Astronautics. Indeed, it is an exceptional student that could master all these interests. In a well-arranged educational program, however, the strong features of the school and student would correspond.

Rocket propulsion

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ROCKET propulsion is one application of the general principle of jet propulsion, which involves forward motion caused by rearward ejection of matter from a propelled body in the form of a high velocity fluid jet. Jet propulsion is fundamentally based on Newton's Third Law of Motion: For every action, there is an equal and opposite reaction. In rocket or jet engines, the force of the momentum of the rearward ejection of the jet stream (generally hot gas molecules streaming from a nozzle) imparts a reverse (i.e., forward) motion or thrust to the device. A very simple experiment illustrating jet propulsion can be conducted by blowing up an ordinary rubber balloon and observing its forward motion when released.

The jet can be generated in two ways: (1) By burning compressed air taken from the atmosphere with hydrocarbon fuel in a combustion chamber, and ejecting the combustion products through a nozzle (*air-breathing engine*, of which the turbojet and ramjet are examples); or (2) by reacting chemicals (propellants), entirely carried, in a similar manner (*rocket engine*, such as liquid bipropellant, liquid monopropellant, or solid propellant system). Both processes produce gases at high temperatures and pressures. This heat energy is subsequently converted to the kinetic energy of a high velocity gas stream by expansion in a nozzle. The chemical rocket engine, not dependent upon air as its oxidizer source, can thus propel a spaceship, which moves in a virtual vacuum, except when landing on a planet.

Let's look further into some rocket propulsion fundamentals. The momentum thrust of the gas stream is given in simplified form by the equation, $F = mv_e$, where m is the mass flow rate of gas and v_e is the exhaust gas velocity relative to the rocket. Conversion to engineering units gives the expression, $F = \dot{w}/g\ v_e$, where F is in pounds of force, $\dot{w}$ is in lb/sec, and v_e is in fps.

If the nozzle exhaust gas pressure is greater than the atmospheric pressure, additional pressure thrust is created, amounting to $A_e\ (p_e - p_0)$, where p_e and p_0 are nozzle exit and atmospheric pressures respectively, and A_e is the cross-sectional area of the nozzle. One can see from this term why a rocket engine designed for operation in the lower atmosphere will deliver more thrust at high altitudes.

The thrust expression then would be, $F = \dot{w}/g\ v_e + A_e\ (p_e - p_0)$. This equation leads to a term called *effective exhaust velocity* (c):

$F = c\ (\dot{w}/g)$, where $c = v_e + A_e\ (p_e - p_0)g/\dot{w}$. Maximum thrust is obtained for any given set of chamber conditions when $p_e = p_0$; this is referred to as the "optimum expansion ratio," and under such conditions, by definition, $v_e = c$.

It is possible to calculate the exhaust velocity (v_e) from the properties of the working fluid. It is equal to the enthalpy change of the gas during adiabatic expansion, expressing the change of heat energy into kinetic energy: $v_e = \sqrt{2J\ g\ (H_c - H_e)}$, where J represents the mechanical equivalent of heat, and H_c and H_e the enthalpy of the chamber gas and nozzle exhaust gas, respectively. Since enthalpy is largely a function of gas temperature and the *number* of molecules of gas present per unit weight (which would be a maximum for a low-density gas), one can see qualitatively the importance of achieving a high combustion temperature and low molecular weight gas product.

By assuming isentropic flow in the nozzle one can also calculate v_e in terms of nozzle inlet and exit conditions:

$$v_e = \sqrt{2\ g\ RT_c\left(\frac{k}{k-1}\right)\left[1 - \left(\frac{p_e}{p_c}\right)^{(k-1)/k}\right]}$$

where T_c is the chamber temperature, R is the gas constant, k the ratio of specific heats (at constant pressure and volume) c_p/c_v, and p_e and p_c the exit and chamber pressure, respectively. This expression is based on a number of assumptions, including perfect gases, no heat or friction losses, relatively small chamber velocity, and chemical equilibrium in the chamber, unchanging during expansion.

Although efficiencies are not commonly used in designing rocket motors, they are useful in evaluating energy conversions in the system. Of interest are the following:

(1) Combustion efficiency—The ratio of the actual to the ideal heat of combustion per unit weight of propellant.

(2) Thermodynamic efficiency—The last equation shows that the exhaust velocity (v_e) will be a maximum when the exhaust pressure (p_e) is zero, a situation present only with the ideal case of infinite expansion ratio. Obviously this cannot be realized, since it would require the complete conversion of the enthalpy or thermal energy of the exhaust gases into kinetic energy. However, if such conversion is taken to represent 100 per cent thermodynamic efficiency, the efficiency (E) can be expressed as:

$$E = \frac{v_e^2}{v_{e\max}^2} = 1 - \left(\frac{p_e}{p_c}\right)^{k\ -\ 1/k}$$

(3) Propulsion efficiency—The ratio of useful work put into propelling the vehicle to total kinetic energy of the exhaust jet. The useful work is $F\ v_v$, where F is the thrust in pounds, and v_v is absolute velocity in fps. The propulsion efficiency then equals vehicle energy divided by vehicle energy plus residual kinetic jet energy:

$$E = \frac{Fv_v}{F\ v_v + {}^1/_2\ \dot{w}/g\ (c - v_v)^2} = \frac{2v_v/c}{1 + (v_v/c)^2}$$

A plot of propulsion efficiency versus v_v/c shows that the former is a maximum when $v_v = c$, in other words, when vehicle velocity is equal to exhaust gas velocity.

Comparison of Rocket Types

Type	Energy Source	Working Fluid	Means of Acceleration	Exhaust Velocity (fps)
Chemical	Chemical	Combustion products	Thermal expansion	12,000
Nuclear	Nuclear fission	Heated gas	Thermal expansion	25,000–30,000
Solar	Solar	Heated gas	Thermal expansion	25,000–35,000
Arc	Nuclear	Plasma	Thermal expansion and/or electromagnetic field	40,000–50,000 60,000–150,000
Ionic	Nuclear	Ions	Electromagnetic field	150,000–500,000
Fusion	Nuclear	Fusion products	Thermal expansion, electromagnetic field	1,800,000

Two other terms widely used in the rocket literature are *mass ratio* and *burnout velocity*. The mass of the rocket (M) consists of two parts, propellant (m_p) and inerts (m_i); $m_p/m_p + m_i$ is called the mass ratio. During rocket flight, the inert mass remains constant but the propellant mass decreases at a rate equal to the loss of propellant gases through the nozzle. The acceleration of the rocket can be expressed as $d_v/dt = -c\, dM/dt$, which integrated over the rocket burning time gives $v_b = c \ln (1 + m_p/m_i)$, where v_b is the terminal velocity at burnout. Achievement of proper burnout velocity is, of course, very important for successful satellite orbiting or escape from the earth's atmosphere.

Specific Impulse

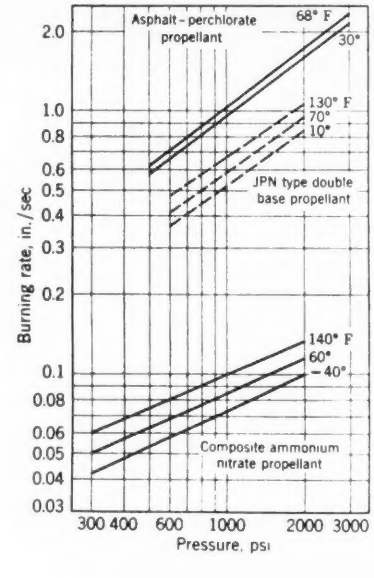
It is convenient for rocket motor designers to use as a performance parameter the thrust delivered per unit weight of propellant consumed per second. This ratio, specific impulse, is defined as: $I_{sp} = F/w = c/g$. When the rocket exhaust gases expand fully to the pressure of the surrounding atmosphere, $I_{sp} = v_e/g$. Total impulse delivered is the integral of thrust (F) over a given time (t), and can be expressed as: $I_t = I_s\, w\, dt$. For constant thrust, $I_t = I_s W$, where W is the total weight of propellant consumed.

Based on the equation $I_{sp} = v_e/g$ and the equation for v_e on page 7, one can calculate a theoretical value for specific impulse in terms of the properties of the combustion gases:

$$I_s = 9.8\sqrt{\frac{k}{k-1}\left(\frac{T_c}{M}\right)\left[1-\left(\frac{p_e}{p_c}\right)^{k-1/k}\right]}$$

where M is the average molecular weight of the gas mixture and other terms are as previously noted. Here, again, we can see the importance of the highest possible gas temperature and lowest possible gas molecular weight, as well as high chamber pressure, for maximum values of specific impulse. (In other words, hydrogen gas taken to high pressure and temperature and then expanded through a nozzle would provide an ideal rocket system.) Such conditions as high chamber temperature and pressure would require heavy chamber walls, with consequent low mass ratio; obviously the optimum combination must be selected. A consideration of the ratio total impulse/total motor weight will show, for example, that a system with an I_{sp} of 200 and mass ratio or 0.5 is equivalent on a weight basis to a system of lower I_{sp} of 175 but higher mass ratio of 0.575.

Burning Characteristics of Some Typical Solid Propellants



The energy in the hot chamber gases is derived from the breaking of initial chemical bonds present in the starting propellant components, and the formation of new and stronger bonds in the product gases. The more extreme these differences are, the better the energy release. For example, in the reaction $H_2 + F_2 \rightarrow 2HF$, the relatively weak H–H and F–F molecular bonds are broken, and the very strong H–F bond formed; in the process considerable energy is released. This fact, coupled with the low molecular weight of HF, makes the hydrogen-fluorine combination one of the best available, from an impulse standpoint.

The above calculation for specific impulse is based on frozen equilibrium (or constant-composition) basis, which assumes that no further chemical reaction occurs during the expansion because of the extremely short contact times in the nozzle (of the order of 0.1 milliseconds). On the other hand, the shifting equilibrium basis assumes that the gases achieve thermal and chemical equilibrium during the expansion process, so that there is partial reassociation of the dissociated molecules (due to the lower temperatures), with consequent further energy release. Therefore the shifting basis yields a higher value for specific impulse.

The liquid bipropellant system consists of a suitable oxidizer-fuel combination, which would ideally have the following properties:

(1) High specific impulse (i.e., high energy per pound of material reacted; low-molecular-weight exhaust products).

(2) Boiling point greater than 90 C (to avoid insulation and/or heavy-walled storage tanks).

(3) Freezing point below −60 C, so that propellants may be handled as liquids over a wide temperature range.

(4) High viscosity index (i.e., slight viscosity changes over a wide temperature range).

(5) Density greater than 0.9 grams/cc (to minimize storage tank weight).

(6) Ease of ignition (a fuel-oxidizer combination which ignites spontaneously on contact is called "hypergolic").

(7) Nonsensitivity to mechanical and thermal shock.

(8) Thermal properties suitable for use as a motor-wall coolant (good thermal stability, high specific heat, and thermal conductivity).

(9) Nontoxic to humans.

(10) Noncorrosive to common materials of construction.

(11) Low cost and plentiful supply (i.e., good logistics).

(12) Possess good long-term storage characteristics (no chemical decomposition, reaction, or gas-buildup).

Ideal Not Yet Realized

Obviously the ideal propellant combination is yet to be found; all systems represent compromises of the above. The table at the bottom of page 10 lists some common propellant combinations.

A liquid monopropellant is a single liquid capable of sustained autodecomposition under the proper conditions. It may be a mixture of several components, such as nitric acid and aniline, or a single compound, such as nitromethane. Obviously the handling of one liquid rather than two has some attractive features, such as fewer valves and less plumbing. The table here lists the performance of several common monopropellants for $p_c/p_0 = 600/14.7$, optimum expansion, and frozen equilibrium.

Material	Theoretical I_{sp} (sec)
Ethylene oxide	170
90% hydrogen peroxide	144
Ethyl nitrate–propyl nitrate (60/40)	195

The liquid bipropellant system in simple form involves a means for bringing fuel and oxidizer from the storage tanks to the injectors, flow

control, and a combustion chamber with expansion nozzle. The storage tanks are generally kept under moderate gas pressure, to maintain a constant head on the pump and to minimize pump cavitation. If the pressure is sufficiently high, this can be used to force the propellants to the chamber; more commonly a turbopump is used (i.e., a centrifugal pump driven by a turbine which is in turn powered by gases from a special gas generator).

These operating principles of a liquid bipropellant motor can be illustrated with reference to the first stage of the Vanguard satellite-launching vehicle, which is shown diagrammatically below. Using kerosene and liquid oxygen, it had a nominal burning time of 150 sec and a thrust rating of 27,000 lb at sea level. The steel thrust chamber was regeneratively cooled by kerosene flowing through helical passages between the chamber's inner and outer shells, on its way to the injector head. The chamber, mounted on gimbals, was hydraulically activated so that the direction of the thrust vector could be changed to provide pitching and yawing moments which controlled the vehicle's attitude during first stage flight. The turbopump delivered propellants as desired and also drove the hydraulic pump for the control system. Power for the turbopump was derived from high-temperature steam, provided by the decomposition of 90 per cent hydrogen peroxide as it passed through a silver-screen catalyst chamber. The second stage of Vanguard was a white fuming nitric acid (WFNA) and unsymmetrical dimethyl hydrazine (UDMH) bipropellant system; the third stage was a solid propellant rocket. The illustration on page 10 shows the assembled Vanguard vehicle—71 ft long, 45 in. in diam (first stage), and 22,600 lb loaded for launching.

Solid Propellants

Solid propellants are solid mixtures (which may be homogeneous or heterogeneous in composition) of an oxidizer and fuel capable of sustained combustion if initiated. In use today are two general types: *double-base* (homogeneous), consisting of cellulose nitrate polymer plasticized with high-energy liquid (such as glycerine trinitrate), where the nitrate grouping is oxidizer and the $-CH_2-$ moiety the fuel, and *composite* (heterogeneous), consisting essentially of a polymeric binder matrix, such as a plastic or rubber (which also serves as the fuel), and a crystalline oxidizer, such as ammonium nitrate or perchlorate. Both types of solids usually contain a number of special ingredients for controlling burning rate, physical properties, etc.

After suitable mixing of ingredients, followed by certain other processing steps, the double-base propellants are processed into the desired grain shape by either mechanical extrusion or casting followed by a thermal curing or "setting" period.

Composite propellants are the oldest form of rocket fuel. Black powder, used for centuries, consists of potassium nitrate oxidizer with sulfur used as both binder and (with charcoal) as fuel. (It is still used as an igniter material today.) Oxidizers which have been used include sodium nitrate, potassium nitrate, ammonium nitrate, potassium perchlorate, ammonium perchlorate, and lithium perchlorate. The two most commonly used are ammonium nitrate and ammonium perchlorate; the nitrate is best as regards price and availability (it is a basic fertilizer ingredient), but the perchlorate possesses marked advantages in density, available energy and processing capability.

Many types of polymers have been used as binder materials, e.g., synthetic rubbers of various sorts, polystyrene, and polyvinyl chloride. Desirable properties of a binder include high energy, which will give low-molecular-weight gaseous combustion products; proper processing characteristics; and proper physical properties so that resulting propellant meets stringent physical handling requirements.

Although composites can also be extruded into proper grain shape, a semi-liquid polymer that can be mixed with oxidizer and cast as a slurry offers many advantages, such as lower cost and larger motor size. Ideally, such a slurry should set or cure to a solid within a reasonable time-temperature combination.

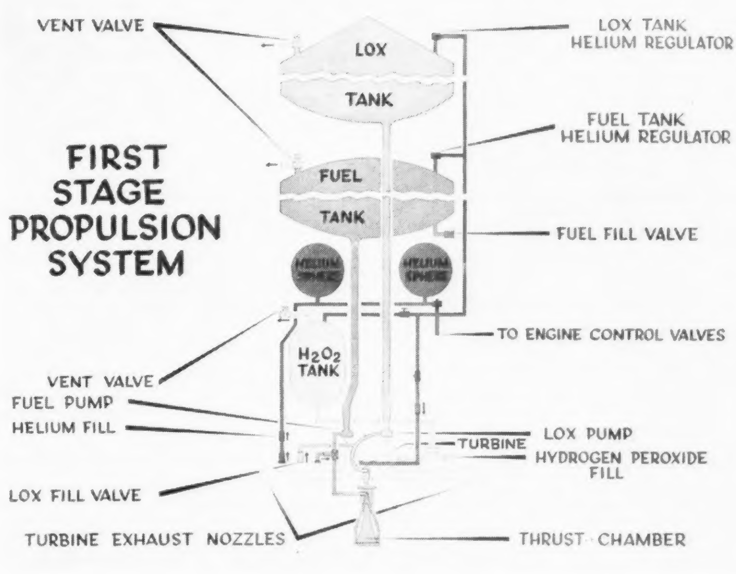
A typical composite would contain 75 per cent ammonium perchlorate, 20 per cent polymer binder and 5 per cent of various additives, which might consist of liquid plasticizer, stabilizers against storage deterioration, and ballistic modifiers for burning rate control. The essential operations of preparing a cast propellant therefore include oxidizer grinding, weighing, conveying, mixing, casting, and curing.

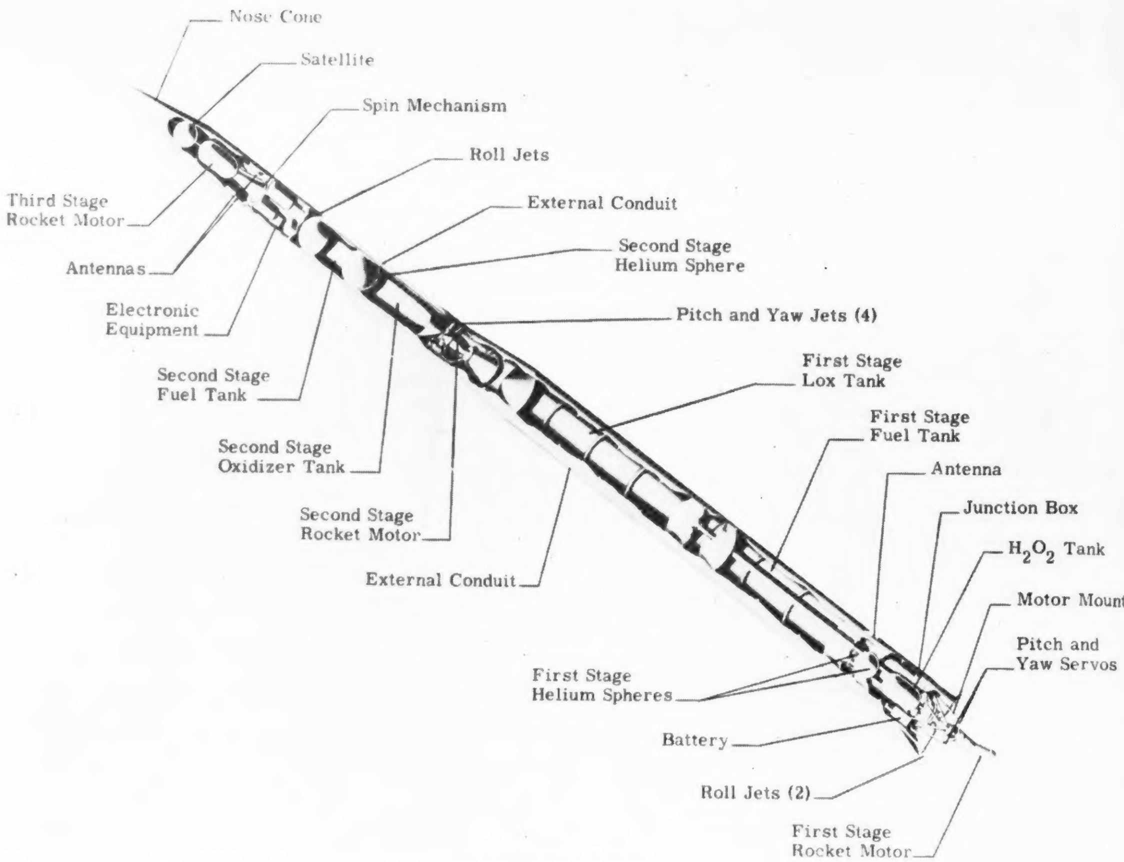
Physical Characteristics

Physical characteristics are of utmost importance. The propellant should not exhibit "cold flow," and should retain flexibility at both high and low temperatures. It must be able to maintain its structural integrity through wide temperature cycles, since cracking can lead to erratic burning and motor blowups.

The propellant grain burns very uniformly on the exposed surfaces at a rate which is primarily a function of the pressure in the combustion chamber, and the temperature of the pro-

Diagram of Vanguard First-Stage Engine





VANGUARD

pellant grain. The rate is expressed as inches (of surface burned) per second (ips), and for most propellants can be approximated by the empirical equation, $r = ap_c^n$, where p_c is the chamber pressure, and a and n are constants for a given temperature.

For practical propellants, r can have values ranging from 0.03 to 2.5 ips. The exponent, n, is a measure of the sensitivity of the burning rate to changes in pressure, and therefore is an important characteristic of any solid propellant. It is desirable for motor design purposes to have n as low as possible. The exponent can be readily determined for any propellant by measuring burning rates of strands of propellant in a pressurized bomb at various pressure levels, and determining the slope of the logarithmic plot of r vs. p_c.

The graph on page 8 shows such plots for several representative propellants. As can be seen, the burning rate of a particular composition is also quite dependent on temperature. This means that adjustment must be made for temperature changes in determining rocket performance, since rate of thrust development cannot be changed during flight of a solid motor, as it can with liquid propellants. This rate change is shown by changes in the value of "a" in the burning rate equation, and is reflected in the burning rate temperature coefficient at constant pressure:

$$\sigma_p = \left(\frac{\partial \ln r}{\partial T}\right)_p$$

Since burning rate is affected by temperature, this is reflected in the equilibrium chamber pressure change with temperature (at constant k, where k is the ratio of the burning surface area to the nozzle throat area), and is expressed by:

$$\pi_k = \left(\frac{\partial \ln p}{\partial T}\right)_k$$

These coefficients are normally expressed as % change/F. The table on page 11 gives appropriate data for several representative propellants.

A solid propellant motor is essentially a propellant-filled pressure vessel with a nozzle and a means for ignition. The critical design parameters are the chamber pressure and the tensile strength of the metal wall. The equilibrium chamber pressure depends upon the rate at which gas is being generated and the rate at which it is escaping through the nozzle. As an approximation, gas-generation rate is a function of propellant burning area (A_b) and gas escape is a function of

Properties of Typical Cast Solid Propellants

	Composite 1	Composite 2	Double Base
Oxidizer	Ammonium perchlorate	Ammonium perchlorate	Cellulose nitrate
Fuel	Polybutadiene-acrylic acid plus aluminum	Polyurethane	with glycerine trinitrate
Theoretical specific impulse at sea level with 1000 psi chamber pressure	250	238	219
Burning rate, r, ips	0.467	0.227	0.45
Burning rate exponent, n	0.236	0.5	0.61
Temp coefficient of pressure, π_k, %/F	0.115	0.13	...
Density lb/cu in.	0.063	0.062	0.057

nozzle throat area (A_t). Therefore we can say:

$$p_c \cong \left(\frac{A_b}{A_t}\right)^{1/1 - n} = k^{1/1 - n}$$

To develop high thrust, both p_c and A_t should be large, which means that the burning rate area should also be large.

This can be accomplished with an *internal grain burning* by having a central perforation to give large surface area. This perforation is often in the shape of a star, since a star grain can be designed so that the burning area remains constant during the entire run. The figure below shows a cross-sectional view of a typical star grain.

Another very important improvement in solid propellant design has been *case-bonded* propellant. With the propellant bonded directly to the chamber wall, and the burning progressing from the interior toward the chamber wall, the wall is effectively insulated from the hot gases by the propellant itself. Therefore "cold-strength" design can be used, with resulting lightweight chambers. For this reason, and the natural simplicity of the solid propellant system, high mass ratios can be achieved (93 per cent has been suggested as feasible).

It must be stated emphatically that both liquid and solid propellant rockets have their respective area of clean-cut superiority, and both will continue to be used. We may briefly summarize the main advantages of each:

Solids: Lower cost, simplicity of design (and therefore higher reliability), ease of handling and start-up (and therefore maximum "readiness").

Liquids: Higher potential specific impulse, ability to be stopped, restarted and throttled (and therefore easier to "program" a specific mission).

Many rocket propulsion schemes have been suggested which do not depend on the energy of a chemical reaction for thrust generation. These can be classified as follows.

Nuclear Fission: A suitable working fluid (such as hydrogen or ammonia gas stored in the rocket) is heated up by passage through a nuclear reactor, and then expanded through a nozzle.

Solar: Solar radiation is reflected by spherical mirrors to a heat exchanger where it heats up the working gas.

Nuclear Fusion: The use of a thermonuclear power plant as an energy source.

Ionic: The generation of ions and electrons by heating or irradiating a suitable surface; the ions are then accelerated by an electromagnetic field. The electric power required is generated by a nuclear reactor and suitable generating equipment. This process can only be carried out in a vacuum; outer space would provide such an environment.

Free Radicals: If a free radical such as $H^{\bullet}$ could be stabilized and stored, and at the appropriate moment of nozzle expansion, give up its rather considerable energy of recombination, very high specific impulse values could be achieved. At the moment, the prospects of such stabilization in a practical system seem remote.

Arc: Creation of a "plasma" of hot ionized gases, by means of an electric arc, and subsequent expansion.

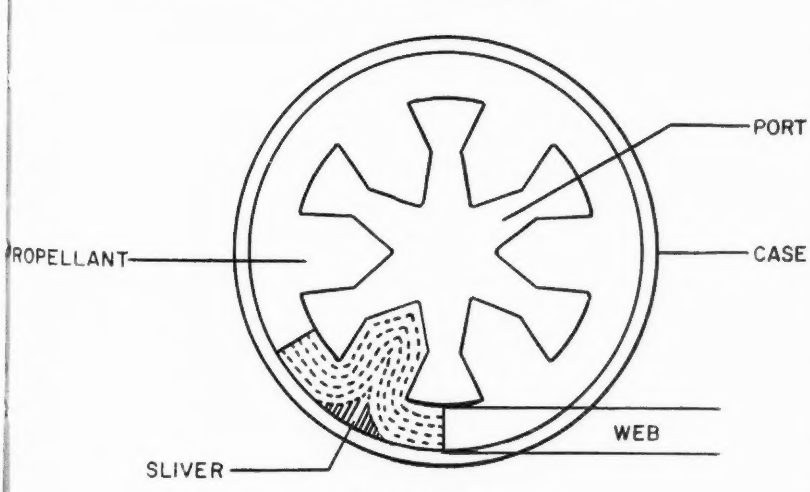
The table on page 7 compares these systems. It should be noted that despite the high exhaust velocities realized, the weight of power plant per pound of thrust realized is very high for these systems. For example, the thrust to engine weight ratio for a chemical or nuclear rocket is about 10–80; for an ionic rocket it is in the order of 5×10^{-3} to 5×10^{-5}.

Theoretical Performance of Several Liquid Propellants

Oxidizer	Fuel	Mixture Ratio, Oxidizer/Fuel	Theoretical Combustion Temp (Deg F)	I_{sp} (sec)
RFNA (22% NO_2)	JP-4 (Jet Fuel)	4.1	5150	238
(red fuming nitric acid)	UDMH (Unsymmetrical dimethyl hydrazine)	2.6	5200	249
N_2O_4 (nitrogen tetroxide)	Hydrazine	1.1	4950	263
Hydrogen peroxide (90%)	Hydrazine	1.5	4170	252
Oxygen (lox)	JP-4	2.2	5880	255
	Ammonia	1.3	4940	232
	UDMH	1.4	5650	261
	Hydrazine	0.75	5370	279
	Hydrogen	3.5	4500	363

Conditions: $p_c/p_0 = 500/14.7$; optimum expansion; frozen equilibrium.

Cross-sectional View of Solid Propellant Grain



Note: Dotted lines show burning pattern.

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Rockets and amateurs

By George P. Sutton

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IN THE past two years, rockets and space flight have caught the fancy not only of the general public, but of the nation's youngsters as well. There are today tens of thousands of youngsters throughout the country, either banded together in some 2000 or 3000 local clubs or working alone or in groups of two or three, with an interest in rockets.

The interest is a healthy one, and should be encouraged. These youngsters are eager to learn, but some of them, unfortunately, are going about it the wrong way. This is the large group performing hazardous experiments with live rockets and the explosive chemicals used in the rockets' propellants. It is a dangerous trend, and one of major concern to parents, teachers, and the AMERICAN ROCKET SOCIETY.

Scope of the Problem

Every week, somewhere in the U.S., several youngsters get hurt simply because they do not know how to handle rockets. ARS has received literally thousands of letters from youngsters (and adults, as well) seeking instructions on how to build or launch rockets, what types of propellants to employ, and what kinds of experiments to perform.

The problem is a very serious one, and one to which ARS has given a good deal of attention. What should we tell these youngsters? Should we encourage them to build and fire rockets? If not, why not? What types of experiments should be suggested?

It is the purpose of this article to try to answer some of these questions.

How dangerous is it? Playing around with rocket propellants is, at best, a hazardous occupation. The table on page 13 shows that rockets, when handled by amateurs, are more dangerous than automobiles, and that injuries resulting from hazardous experimentation appear to be 600 times more frequent than the occurrence of polio. Of the 1500 or so youngsters who got hurt last year, for example, some 350 were in some way permanently crippled or disfigured, many losing an eye, a finger, a hand, or a limb. Even though amateur rocket injury statistics are based on meager data, the trend is clearly a frightening one.

Even to the qualified professional, rockets are dangerous. For example, I personally know of nine experienced men in the rocket business who have been killed in explosions or fires involving rocket propellants. Some were good friends of mine. They were not careless, and they knew all the tricks and safety precautions of the trade. These chemicals are just very deceptive and dangerous. It is not too well known that rocket fuels can be potentially several times more energetic than TNT or some of today's best gunpowders, or that just a very small change in composition or formulation can turn a smoothly burning propellant into a vicious explosive.

ARS has studied the problem carefully and has recommended a policy of avoiding experiments with hazardous chemicals. The ARS Board of Directors has on various occasions passed resolutions which discourage amateurs and youngsters from working with or firing rockets, or from conducting experiments involving rocket propellants of any kind, and encouraging them instead to study and undertake other nonhazardous projects.

This policy has been adopted by a number of agencies including the National Safety Council, the Department of Health, Education, and Welfare, the Department of Defense, and the Boy Scouts of America. Many of our prominent rocket men have repeatedly warned young amateurs on this subject.

The message to inexperienced amateurs and youngsters, then, is: Don't play with rockets. The vast majority of young people take this advice to heart and work on other interesting but nonhazardous space projects. But there are a few dedicated youngsters who just have to build, assemble, test, or launch rockets.

The next few comments are specifically intended for these determined young experimenters. They serve to demonstrate why the ARS has always taken a very strong stand against this type of experimentation, and what the youngster (or adult) who is determined to experiment is up against.

Things to Check

What should the prospective rocket enthusiast look into before he actually undertakes any experiments? Here's a check list of five principal items:

1. *The hazards:* First, youngsters must learn exactly what the hazards are. Knowledge of what might go wrong, when a rocket is most dangerous, when it is likely to cause a fire or blow up, which propellants are toxic—all this should be studied and understood.

Some experiments are more risky than others. A study made by a special committee of the Southern California Section of ARS (soon to be published by the Society) rates the following as the most hazardous operations: Filling, loading, grinding or mixing of propellants, preparation of

Relative Hazards of Various Amateur Rocketry Projects*

Very Dangerous

Igniter preparation; solid propellant preparation (grinding, mixing, curing); solid propellant loading

Danger Not Very Predictable

Loading of many liquid propellants; storage and handling of monopropellants; flight testing; static firing

Some Hazard, Even with Precautions

Igniter installation; guide-line launching; assembly of commercial solid propellant rockets; launching of steam rockets

Very Small Hazard

Water-gas plastic rockets; CO_2 guide-line rockets; design and construction of radios or instruments; design and construction of propulsion hardware

No Hazard

Model design and building (nonpropulsive); study of rocket principles

* Based in part on data from the Report on Amateur Rocketry prepared by an Ad Hoc Committee of the ARS Southern California Section.

igniters, flight tests, and static firings. The table on page 12 gives such a rating in greater detail.

While it is pretty well accepted that rockets sometimes blow up during ignition or in the launching operation, it is not too well known that the actual loading of the rocket with propellants is perhaps the most dangerous operation of all. This is particularly true with solid propellant rockets, some monopropellants, and all types of igniters. Almost all the accidents involving professionals occurred when the rocket was filled with the propellant or when the propellant was mixed or cured.

During the launch, you expect a mishap and generally take suitable precautions, but in the loading operation your hand is right at the point where you have the greatest danger of an explosion. A good friend of mine blew himself up while trying to assemble dangerous propellants in his shop, and this was a man with many years of experience handling rockets, and one of the best chemists in the business.

Sickness, Accident, or Death Rates for Polio, Automobiles, and Amateur Rocketry

	Sample Size	Number Injured	Injured Per 10,000 Per Yr	Killed	Death Rate Per 10,000 Per Yr
Polio	150,700,000	33,344 (in 1950)	2.2	—	—
Autos	48,600,000	1,200,000 (in 1950)	244	35,000 (in 1950)	7.2
Amateur Rocketry Experiments	12,000	1500 (in 1958)	1250	15 (in 1958)	12.5

Killed During Demonstration

Last year, a science teacher was killed while demonstrating a rocket to his science class in Texas. He may have been a trained scientist but he apparently did not appreciate the dangerous nature of rocket propellants.

Let me quote a few passages from the report referred to earlier:

"Even the tiniest rockets, with as little as 0.0005 lb of propellant, are potentially lethal. Yet the smallest amateur rockets tend to use more than a quarter-pound of propellant. No chemically-powered rocket is safe.

"Some experimental propellants are so pressure-sensitive that all rockets using them blow up. Neither amateurs nor professionals can predict whether a new propellant will fall into this category.

"Relatively complex, expensive equipment is needed to manufacture propellant charges large enough to allow positive retention in the rocket during accelerated flight. Loose or pressed powders, resembling amateur propellants, are unreliably trapped and unpredictable in performance."

2. *Liability:* The second item on the check list is the liability in case of accident. Who is responsible if there is damage to people or property? What are the legal obligations of the man who is the technical adviser to the group, the man who supervises the experiment, the organization on whose property the experiment is performed, or the parents of the minors who might be responsible?

To begin with, it is essential to consult a competent attorney who can help draft suitable papers so that there is no question as to who is liable (and for what) if there is an accident. And these papers have to be drawn up carefully, because they must be valid in court. You may learn that most of those participating in the experiment can have their own personal property and salaries attached to the full extent of the damage claim. Are you willing to gamble with your belongings?

Not so long ago, a youngster in San Bernardino, Calif., lost three fingers in a rocket explosion. Can he expect reimbursement from the man who supervised the test? Or are the parents of the youngster who actually lit the rocket responsible for the loss of his fingers? In another typical accident in the Mojave desert, a crew of young people successfully launched a homemade rocket which came down and hit a parked car and went right through the hood and manifold. Who is responsible for paying the cost of the car's repairs?

Check Local Ordinances

3. *Legal restrictions:* The third point involves a careful check of state laws, city ordinances, and applicable regulations. There are many laws and ordinances relative to the handling of explosives and ammunition, the sale of explosives, and the storage of hazardous chemicals. These vary from community to community and from state to state, and must be investigated. A good many of these statutes already apply to rocket propellants.

Not so long ago, there was an explosion in a South Pasadena garage in which one of the members of a local rocket organization was storing chemicals. Fortunately, no one was injured. He did not know that he was violating a statute and was therefore legally at a disadvantage, for ignorance of the law is no excuse. He was liable not only for direct damages but also had to satisfy some neighbors who felt that the peace had been disturbed and that they had been emotionally disturbed as well.

Today, many new laws and regulations are being discussed, proposed, and enacted in various states, counties, communities, and cities. These laws specifically deal with the hazards connected with the preparation and launching of rockets.

A good many officials in fire departments or safety organizations appear willing to help. In some areas, special permits are needed each time a rocket is tested or fired.

Hazard to Air Traffic

One of the regulations to check is the legality of the flight. It might be a surprise to learn that you can not launch rockets anywhere near an airport. If you do, the Federal Aviation Agency can get after you. Also, discussions are under way to require a permit for a rocket that goes to any reasonable altitude because it presents a potential hazard to air traffic. One aircraft accident in California is attributed to just such a cause.

4. *Supervision:* This is one of the most important items on the list. How experienced and qualified is the adult adviser or instructor who works with the youngsters? Has he loaded rockets before? Does he really know the safety precautions involved in handling dangerous chemicals? Or has he only read books about it? Does he know the chemicals? Will he understand why there is sometimes a fire danger without an explosion hazard?

Does he know the antidote for a youngster who gets some propellant in his eye? What should be the rules about carrying matches in the propellant preparation area? How, where, and in what quantities should igniter squibs be stored?

These are some of the questions a good adviser should be able to answer. He should also have several years of experience in the preparation and testing of the type of rocket the group wants to work with. If he does not know his stuff, it would be far better to postpone hazardous experiments and look for a more qualified man. Unfortunately, there is no guarantee that even a top-notch adviser will prevent accidents. At best, he can only minimize them.

5. *The benefits:* The last question a youngster should ask himself is: What will I learn if, against all odds, I do manage to launch the rocket successfully? It's usually a very short test, lasting only a few seconds, and it is rather hard to see or catch with a camera. Are the many months of preparation worth the effort for that short thrill? Will there be any permanent compensation for the hours of dangerous work with chemicals potentially more powerful than some of the best explosives?

Avoid Experimentation

All these questions should be carefully asked and answered. The AMERICAN ROCKET SOCIETY, having studied the question very carefully, feels certain that the only possible conclusion that can be drawn is that experimentation with live rockets must be avoided.

Nonhazardous Projects

There are, however, a number of projects which are educational and beneficial, yet nonhazardous. I have steadily encouraged my young friends to work on such projects. I believe there are at least 100,000 youngsters in our country who are doing or recently have done this type of thing intelligently on a more or less organized basis. Here are just a few examples.

One of the best ways to channel the interest of youngsters away from hazardous experiments and toward useful, productive study is by interesting them in science per se. The study of mathematics, chemistry, physics, meteorology, or any other branch of science connected with space flight can indeed be a worthy and rewarding undertaking. This can be done individually or in groups—in space flight and rocket clubs, in existing organizations such as the Boy Scouts or Science Scouts, or through individual directed study. It can consist of reading books and magazines, seeing films or merely listening to people who know what they're talking about.

For example, in the San Fernando Valley in California, there is a group of scouts sponsored by Marquardt Aircraft Co. which has become extremely interested in science. This group regularly secures technical lecturers and demonstration equipment from local aircraft firms, schools, and rocket or missile manufacturers. It has been a most interesting group to belong to, and parents have attended just about as regularly as the youngsters.

Another example is that of James Samuel, who made a study of micrometeorites and entered a display giving his findings in the Lehigh Science Fair at Allentown, Pa. I know of one young man who made a library search of meteor phenomena recorded in the last century. He looked at old books and found many instances where bright objects were sighted streaking through the sky. In so doing, he uncovered and collected data that were heretofore not put into suitable form, and thus made a significant and original contribution to science. Another boy, William P. Love, showed his *design* for a liquid rocket at the Florida State Fair.

One excellent example was the Frontiers of the Space Age Conference put on by a group of public spirited citizens in Oklahoma City last May. Here, prominent speakers gave talks of interest to a group of 7000 enthusiastic high school students selected from all over the state of Oklahoma, who heard lectures by top authorities on such subjects as ballistic missiles, space flight vehicles, space medicine, rocket engines, special materials, and the educational needs of space flight.

It is relatively easy to get help and scientific talent to do some teaching or some talking when hazardous experiments are not involved. ARS is willing and able to provide such help by furnishing lists of available books and movies on the subject, by distributing special brochures and pamphlets, and by suggesting speakers for groups which are interested.

The second suggestion is actually to build something. One group of youngsters studied and built a scale model of a four-stage moon rocket, showing the proportions of the various stages and components. The wooden model was 10 ft high and was entered in a science competition. Other groups have built simplified versions of missile components, such as an engine gimbal, a telemetering system, or a space-simulated closed-cycle oxygen supply and carbon-dioxide regenerator for experiments with mice.

The next suggestion is to take these projects and studies and put them into the form of reports, slides, records, pictures, albums, or posters, and enter them in fairs, expositions, school exhibits, or youth contests. This can be a rewarding undertaking, in which recognition is given for hard work and study. A ribbon or a medal means a great deal to a youngster. This method also perpetuates the effort and lets other youngsters reap the benefits.

There is a series of actual launching experiments which are nonhazardous but still "experimental" in nature. For example, there are on the market today some rockets which are nonexplosive and relatively nonhazardous. One is a water-air rocket in which air is compressed by means of a hand pump to expel half a tank of water. Then there is a model where soda is mixed with water to provide gas pressure in the water tank. With rockets of this type, you cannot usually produce an explosion. At worst, you may get wet.

Educational Activities

In these projects, youngsters can observe the mechanisms, compute and observe trajectories, find ways and means for recovering the missiles, or carry out simple tests by putting various devices into or onto the nose. Another suggestion would be to build a multi-piece, instructional space vehicle model which can be used in the classroom for subsequent science classes.

One group of rocket enthusiasts discussed the possibility of devising a simple homemade missile telemetering system, putting it into a car, and then tracking it by sending signals on the direction, altitude, and number of miles traveled by the car. The information could then be relayed to a data center where the group figured out where the car was going or had been. It sounds like a wonderful educational game.

For parents and teachers, it is perhaps most important to channel the enthusiasm and interest of these youngsters in a direction which will be beneficial both to the kids and to the country as a whole. Young people who have a flair for technical studies should be helped and oriented toward scientific studies, rather than permitted to undertake dangerous projects.

Parents, teachers, civic leaders, and scientists seem agreed that this is the best course. This country can use all the top-notch scientific and technical talent it produces, but basement rocketeers and thrill-seeking rocket amateurs do not fill the bill.

Based on an address presented at the ARS 13th Annual Meeting in New York Nov. 17-21, 1958.

The rocket: An old idea, an old challenge

By Saunders B. Kramer and Nancy Putnam, *Lockheed Missile & Space Div., Sunnyvale, Calif.*, and Alex Chwick, *Sperry Gyroscope Co., Great Neck, N. Y.*

THE HISTORY of rocketry clearly demonstrates the tortuous path an idea often takes before it comes to fruition.

The first hint of the rocket idea occurs in legends about the flying pigeon of Archytas, a wooden bird built about 360 B.C. Very little is known about it except its renown as a marvel of mechanical ingenuity. When the exaggerations of early writers are discounted and their stories logically analyzed, it seems possible that the pigeon was suspended by a string or rod and made to fly by means of a jet of steam or compressed air.

If lack of detail about the flying pigeon is annoying, there is compensation in the story of the Aeolipile, a jet or reaction engine built by Hero of Alexandria in the 2nd century B.C. One can see in Hero's invention the germ of the idea that developed into the steam engine, the steam and gas turbine, the jet-propelled plane, and the rocket. However, the times were such that Hero's idea was destined to remain only a toy for scholars and philosophers.

Chinese Developments

While Greek rocket development lay dormant, rockets were being developed on the other side of the earth. We have no idea when the work began, since the record is blank for 10 centuries. However, an ancient Chinese manuscript, well illustrated, tells the story of the battle of Pien-King in 1232 A.D. between the Chinese and their Tartar enemies. The account tells how the defenders of the city used "arrows of flying fire." The description and illustrations indicate that these were actually rockets, and not ordinary arrows dipped in pitch. There may have been centuries of effort behind these 13th century battle rockets, but records are scanty and one can only speculate.

During the decades which followed, the Chinese perfected the art of making and using gunpowder, and around 1270, Marco Polo and others brought the idea of gunpowder and its use in rockets back to Europe. It is not surprising to find rockets mentioned in the writings of Roger Bacon and Albertus Magnus at the close of the 13th century. One Marcus Graecus wrote a detailed report on rockets based on these writings, describing them fully.

Just when the first European rockets were used is difficult to say, but by the beginning of the 15th century rockets were widely known. In 1405, a treatise by a German military engineer mentioned three types and advocated their use in warfare. Another military expert, Joanes de Fontana, an Italian, showed real imagination in rocket design. In his book of war instruments are drawings of rockets disguised as rabbits, pigeons, and fish, and equipped with rollers to carry them towards the enemy lines. De Fontana even sketched a rocket car whose design and construction seem practical. There is no indication that his ideas were ever used, but they show the trend of thinking about rockets at that period.

In the 15th century, the cannon and smaller firearms were slowly being brought to perfection. For a while, both cannon and rockets were used, but the advantages of the cannon over the crude rocket soon became evident, and rockets gradually lost their military importance. Even before 1500, rockets had become obsolete as weapons, and for the next three centuries their use in Europe was limited to fireworks and signaling.

The progress of rockets from 1000 to nearly 1700 A.D. was slow. During all this time, there was little or no understanding of how the rocket actually worked. Explanations offered by scholars were confused by the mysticism in which medieval scientific ideas were steeped. Then, in 1687, Sir Isaac Newton gave the world the explanation for the dynamics of the rocket in his famous "Laws of Motion." His theory of action and reaction is not only a 17th century milestone, but also the key to understanding the mechanics of all rockets, from the bazooka to the lunar probe vehicle.

While rocket experimentation in the early 1800's was mostly on war rockets, Claude Ruggieri of Paris developed rockets for carrying rats, mice, and other small animals. These experimental rockets had automatic parachutes which carried the animal safely to earth at the end of its rocket trip. Ruggieri's experiments reached a climax about 1830, when he announced a rocket large enough to carry a ram aloft. The actual flight, however, never came off.

Previously, in 1804, Sir William Congreve and his predecessors at the Woolwich Laboratory in England had again taken up the work of adapting rockets for war use. By 1806, he had developed a product so satisfactory that, in October of that year, during the Napoleonic Wars, he obtained permission to assail the city of Boulogne with boats fitted for firing salvos of rocket projectiles. The Congreve rockets, which were used again in 1807 by the British against the Danes at Copenhagen, weighed 32 lb, with the casing weighing 7 lb and the balance fuel. They were 3 ft 6 in. in length and 4 in. in diam, and had metal cases. The only stabilizing device was a 15-ft stick fastened to the side in the fashion one finds in modern fireworks skyrockets. The rockets proved ballistically inaccurate and were later replaced by others with centrally located sticks—with somewhat better results.

Use of War Rockets

Rockets had now established a place as an auxiliary to, and sometimes a replacement for, field artillery and ship guns of moderate caliber. They distinguished themselves at Walcherin (1807) in the passage of the Adour and at the Battle of Leipzig (1813). Perhaps the most far-reaching achievement of the Congreve war rocket, however, was at the Battle of Bladensburg during the War of 1812. Here, an intensive rocket barrage, directed against Stanbury's American brigade, caused the regiments of Schultz and Ragan to break and flee. This was the signal for a general rout which left the city of Washington unprotected and led to its immediate capture and subsequent burning by the British forces.

A similar barrage was employed the following month during the attempted capture of Fort McHenry in Baltimore Harbor. These rockets, whose "red

glare" is so vividly recorded in the "Star Spangled Banner," were not signal flares, but missiles carrying warheads loaded with substantial amounts of explosive—literally, "bombs bursting in air."

For all the improvements he made, however, Congreve was unable to determine a technique for stabilizing his rockets in flight other than his inadequate guidesticks. The need for a more ballistically stable rocket was evident. In some instances, a rocket actually returned to the ship from which it had been fired.

Improved Stability

Finally, in 1850, William Hale found a method to increase the stability of the rocket, and at the same time to replace the awkward guidestick. He inserted three small curved vanes in the path of the jet, causing the rocket to spin rapidly in flight. This idea was adapted, of course, from the rifled artillery shell.

Hale's rockets were used for several years in the dwindling rocket brigades of Europe, but rifling improved artillery so much that the war rocket steadily lost out.

The modern high-altitude rocket, however, owes at least two of its features to Congreve and his successors: The metallic streamlined case and the stabilizing fins or vanes introduced by Hale. To the peacetime rockets of the 19th century it owes another feature—the idea of multiple or step construction, today a vital part of interplanetary rocket design. The latter came about through experimentation with lifesaving line-carrier rockets in an effort to achieve greater distance without too great an expenditure of fuel. In 1835, Colonel Boxer of the Royal Laboratory produced a rocket of great range by joining two ordinary rockets end to end in such a manner that, when the first had burned out, the second commenced burning to prolong the flight of the rocket. This scheme had been suggested earlier by a man named Frazier, who apparently failed to make any practical test of it.

Scientific investigation of rockets did not begin again in earnest until the 1920's, with one notable exception. In 1903, Konstantin Tsiolkovskii, a Russian school teacher and early researcher in astronautics, proposed the revolutionary idea of designing rockets which would use liquid fuels. Although eminent scientists encouraged him, he failed to influence experimental researchers in Russia, and his name remained unknown elsewhere because nobody translated his writings.

One of the first modern publications on rocket theory was Robert H. Goddard's "A Method of Reaching Extreme Altitudes," published in 1919. Dr. Goddard's interest in this aspect of the rocket grew from the demand for a more efficient device for collecting weather data than the slow and cumbersome weather balloon.

In his first laboratory experiments, he definitely proved the fact, then much doubted, that a rocket would work efficiently in a vacuum. Of equal or even greater importance, he worked out in detail the mathematical theory of rocket staging and stated that with this method it was theoretically possible to build a vehicle that would reach the moon.

He first experimented with powder as a propellant and showed that, by adding a tapered nozzle and making the rocket motor strong enough to withstand higher pressures, the efficiency of the rocket could be greatly increased. He also mentioned liquid fuels, but, like Tsiolkovskii, was unsuccessful in his efforts to interest higher authorities.

Although "A Method of Reaching Extreme Altitudes" is recognized today as a major contribution to rocket research, it did not create as much stir as one might suppose. Perhaps its title and treatment created the impression that it was of interest to physicists and meteorologists only. More likely, however, is the fact that its practical value could not be widely appreciated at that time.

Granted Government Funds

Whatever the fate of the paper, Dr. Goddard's experiments did not go unnoticed. During WW I he was granted government funds, under the control of the Smithsonian Institution, to develop long-range rockets for military purposes. With these funds, he and an associate, C. N. Hickman, developed single-charge rockets propelled by double-base powder (40 per cent nitroglycerin and 60 per cent nitrocellulose), and demonstrated them at the Aberdeen Proving Grounds in November 1918. These rockets weighed from $1^1/_2$ to 17 lb, and were fired from lightweight launchers held by hand. Designs of a 4-in. rocket to be fired from airplanes were also demonstrated, but while these demonstrations were in progress, the armistice was signed and development work dropped. The U.S. settled down to demilitarization, and government-supported research on rockets was not seriously resumed until 1940. Dr. Goddard continued his investigations on high-altitude rockets with funds donated by the Guggenheim Foundation.

During the period from 1920 to 1922, Goddard worked in his spare time with grants from Clark Univ. testing liquid fuels of various types. He came to the conclusion that oxygen and hydrogen were the most powerful reactants but added that ". . . it seems likely that liquid oxygen and liquid methane would afford the greatest heat value of the combinations which could be used without considerable difficulty."

Oberth's Contribution

About this time, the publishing firm of R. Oldenbourg in Munich put out a paper-covered pamphlet of less than 100 pages with the title, "Die Rakete zu den Planetenräumen" (The Rocket into Interplanetary Space) by Hermann Oberth, a professor of mathematics from Transylvania. The introduction began with four numbered paragraphs which read as follows:

"1. The present state of science and of technological knowledge permits the building of machines that can rise beyond the limits of the earth.

"2. After further development, these machines will be capable of attaining such velocities that, left undisturbed in the void of space, they will not fall back to earth; furthermore, they will even be capable of leaving the zone of terrestrial attraction.

"3. Such machines can be built to carry men (probably without endangering their health).

"4. Under certain circumstances, manufacture of such machines might be profitable. Such conditions might develop within a few decades."

Then Oberth added: "In this book, I wish to prove these four assertions. . . ."

The book dealt with more or less general questions of rocket motion, described an assumed high-altitude rocket and concluded with general prophecies about probable achievements. Oberth also described a theoretical spaceship and developed the first sketchy plan for a space station.

The four assertions were subjected to step-by-step mathematical analysis. Rocket flight beyond the atmosphere was dissected mathematically and found to be a problem in fuel consumption. This led to an investigation of the rate at which fuel was consumed, and this was found, in turn, to depend on exhaust velocities. This theoretical reason alone was sufficient to decide in favor of liquid fuels, and particularly gasoline, known to have more than twice the exhaust velocity yielded by ordinary rocket powder.

Oberth did not know about Tsiolkovskii's forgotten articles, in which the Russian schoolteacher had come to

the same conclusions. Nor did Oberth or anyone else know that Dr. Goddard was actually experimenting with liquid fuels at that time, under enormous and unnecessary secrecy.

At first, Oberth's book met with some opposition from European scientists, but eventually they accepted his ideas. This encouraged others who had similar ideas to make public their theories. Soon, all Europe was rocket conscious and scientific research got under way. After early attempts to fly rockets ended in failure because of motor difficulties, European scientists began directing their research to the construction of better motors. This research continued openly until the Nazis came into power.

Meanwhile, in the U.S., on March 16, 1926, Dr. Goddard successfully launched the first liquid-fueled rocket at Auburn. The rocket traveled a distance of 184 ft in 2.5 sec which would make the speed along the trajectory about 60 mph. Other short flights of liquid oxygen-gasoline rockets were made in Auburn, one, on July 17, 1929, attracting public attention when someone who witnessed the flight from a distance reported that he had seen a flaming aeroplane. This was the experiment headlined all over the world as "Explosion of a Goddard Rocket."

In his second report, Dr. Goddard stated that this rocket, of the tail-drive type, carried a small barometer and a camera, both retrieved intact after the flight. Additional tests were performed in 1929 and 1930 at Fort Devens, Mass., and later at Mescalen Ranch in New Mexico.

German Society Formed

Meanwhile, a few years earlier, in 1927, the German Rocket Society (actually Verein für Raumschiffahrt, or Society for Space Travel) was formed by a group of amateur rocket enthusiasts, while a few years later, in 1930, the American Rocket Society was formed as the American Interplanetary Society. In the early '30's, both the German and American societies, as well as individuals, performed a number of rocket experiments with varying degrees of success.

As this decade began, Dr. Goddard started his research in the problem of automatically stabilized vertical flight. The first rocket flight with gyroscopically controlled vanes was made on April 19, 1932. Stabilization was achieved by forcing vanes into the blast of the rocket by means of gas pressure controlled by a small gyroscope. In March 1935, another gyro-stabilized flight was carried out, the rocket attaining a height of 4800 ft, flying a horizontal distance of 13,000 ft, and reaching a maximum speed of 500 mph.

Between this time and the outbreak of WW II there was only silence from the formal strongholds of science and engineering in this country. At a time when research was seriously undertaken in Britain and Germany, the U.S. seemingly abandoned interest in rocketry. Nothing was heard from Goddard except a list of patents. After Pearl Harbor, it became known that he had resumed work for the Navy, mainly, it appeared, on devices for rocket-assisted takeoff for aircraft. Under grants from the Guggenheim Foundation, Goddard was also pioneering a liquid-fueled gyro-controlled rocket very similar to the German V-2 dropped on London in 1944.

The Germans and the English had begun to develop rocket weapons several years before WW II. In 1933, Germany began the first experimental work at Peenemuende with the 330-lb A-1 rocket. They followed it in 1934 with the A-2, which reached a height of 6500 ft. Then about 1937, a research and development station was founded at Peenemuende. A whole series of rockets was designed and intensive effort devoted to their practical construction. These projects were indicated by the symbols A-1 to A-10, the best known being the A-4, or V-2, the work of Walter Dornberger, Wernher Von Braun and their collaborators.

In October 1942, the first successful launching of the V-2 rocket took place. The rocket weighed over 12 tons, was 46 ft long and about 5 ft in diam. The fuel, consisting of 7600 lb of alcohol and 11,000 lb of liquid oxygen, burned for about 65 sec and produced a thrust of about 68,000 lb. With this thrust, the V-2 could reach a maximum height of 60–70 miles. It is interesting to note that the last rocket in the German series, the A-10, though not an operational vehicle at the time, was designed as an ICBM for use against eastern American cities.

British investigations, begun in 1934, were mainly directed toward anti-aircraft rockets utilizing cordite powder (nitroglycerine and nitrocellulose). These fin-stabilized barrage rockets reached altitudes of 20,000 ft and carried several pounds of high explosives. The British were the first to fit some of their invasion boats with barrage rockets, and thousands of them were fired during the invasion of France.

Developments in the U.S. did not get under way in earnest until 1940, when Dr. Hickman, a Bell Telephone Laboratories physicist who had worked with Dr. Goddard as a graduate student in 1918, wrote to Frank Jewett, head of Bell Labs and president of the National Academy of Sciences, outlining the advantages and uses of rockets, especially as applied to the new blitz techniques which the Germans had developed. Dr. Jewett then persuaded the National Defense Research Committee to sponsor a program under the direction of Dr. Hickman and Army Capt. L. A. Skinner, an experimenter with rockets from 1933 to 1940.

Bazooka Rocket Developed

Under the direction of these men, the bazooka rocket was developed. The bazooka was about 21 in. long, weighed a little more than 3 lb and was fired from a $4^1/_2$-ft launcher. Designed as an anti-tank weapon, with a hollow-charge warhead weighing less than 2 lb, it was capable of penetrating 4–6 in. of steel.

At about the same time, the Air Force and Navy also began to support rocketry. By virtue of guiding light from Theodore von Karman and Frank J. Malina, the Air Force pushed the development of jet-assisted takeoff (JATO) units at the Guggenheim Aeronautical Laboratory of the California Institute of Technology and the Jet Propulsion Laboratory, founded by von Karman and Malina. The Navy, through the urging of C. C. Lauritsen, undertook development of a variety of barrage and aircraft rockets, first at CalTech and later at the vast desert expanse of the U.S. Naval Ordnance Test Station in the nearby Mojave Desert.

Studies of jet propulsion and rocket development spread rapidly from such centers of enlightenment to groups in universities, industry, and government. WW II saw in consequence a rapid growth in rocket technology in this country. Unfortunately, the main stream of work and interest ran little beyond a limited military goal, with emphasis on small- and medium-caliber artillery rockets and JATO units.

The history of rocketry since the end of WW II is too well-known to warrant repetition at this time. In the past year and a half, U.S. and Soviet achievements in the astronautics and missile fields have made the potential of the rocket vehicle for peace as well as war obvious to all.

With artificial earth satellites, lunar and planetary probes, and, in the not-too-distant future, manned space vehicles a reality, rather than a dream, the idea of rocketry has come to full bloom. And, just as it has through its long history constituted a challenge to Man, it continues to offer an ages-old choice: Accept the challenge and survive, by bending the idea to useful ends—or perish.


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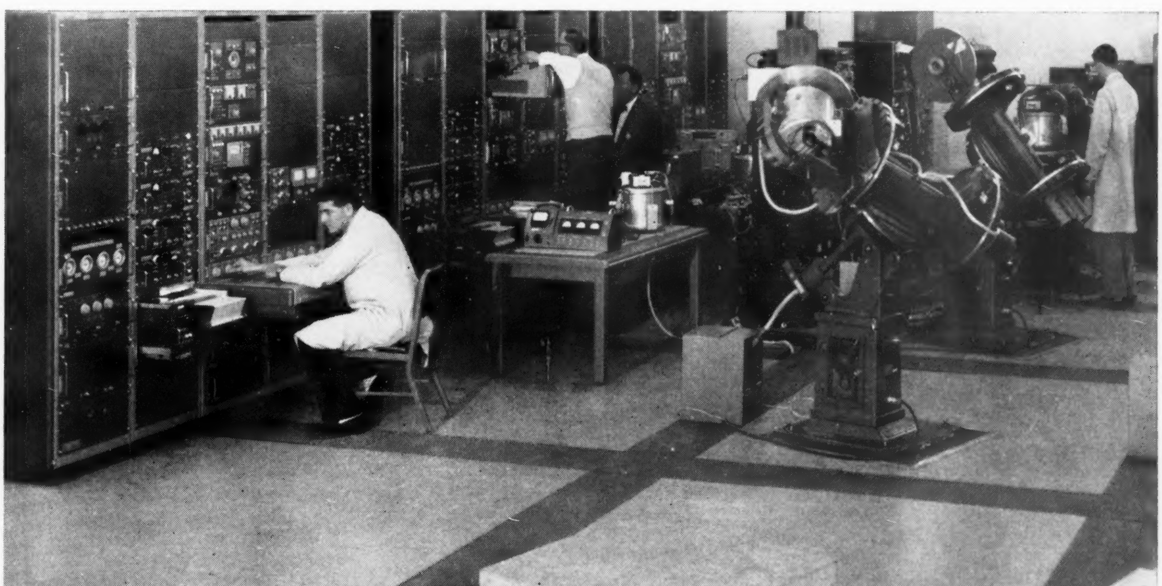

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Astrodyne Presents
John F. Tormey
on
"Opportunity in the Solid Rocket Industry"

WEBSTER'S New Collegiate Dictionary defines *opportunity* as "fit time; a favorable juncture of circumstances; a good chance."

Never in the comparatively brief history of rocket propulsion has this definition been more applicable than it is today. And never has the definition been more appropriate than when applied to the expanding field of solid propellant propulsion devices used in today's rocket industry.

Webster's definition is especially accurate and timely when applied to Astrodyne, Inc., and its place in today's solid propellant rocket industry. Never has a "favorable juncture of circumstances" produced a more "fit time, a better chance" for the rocket engineer seeking opportunity.

These circumstances—which are available today at Astrodyne—are a new company, a vast facility with growth potential, important engineering positions that must be filled, a number of projects as challenging as space itself, and a need for imaginative thinking.

Astrodyne is a new company that was organized specifically in recognition of the tremendous potentials of the solid propellant rocket industry. North American Aviation, Inc., and Phillips Petroleum Company formed Astrodyne as a jointly owned corporation and, thus, brought together two broad backgrounds in rocket propellants and rocket hardware.

And from these two companies came Astrodyne's key leadership, teamed to manage America's major solid propellant missile projects. Rocket and administrative specialists from the two parent companies have been brought together at Astrodyne to direct an experienced and diversified organization capable of handling the most complex missile projects.

Herein, then, lie two of the special circumstances that spell opportunity for the engineer or scientist looking to the future. The one circumstance being that of a new company with its entire future before it—the other being that of challenging career openings working with a hand-picked team of rocket specialists.

The third circumstance, that of challenging projects, also is found at Astrodyne. Built on the foundation of Phillips' Rocket Fuels division, Astrodyne and its current personnel have a broad background in solid propellant rocketry. The scientists and engineers now at Astrodyne developed the first solid propellant JATO unit to satisfy all Air Force requirements; developed and successfully test fired a solid propellant rocket that produced one of the highest known thrust ratings attained in a single rocket motor; and pioneered in the development of complex hardware for the biggest rocket engines in the nation's defense arsenal.

These people have brought their new company special recognition through their development work in superior solid propellant gas generators; powerful and reliable rocket motors for test sled applications; and large Zero-launch booster motors.

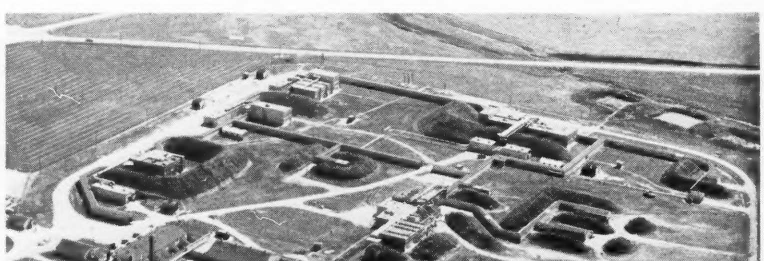
Today, Astrodyne is applying this knowledge and experience in the quest for more powerful cast solid propellants, the development of lightweight plastic and metal rocket cases and hardware, and the design of more sophisticated control devices.

From these major goals stem a multitude of challenging projects—and outstanding opportunities for the engineer and scientist capable of imaginative thinking. Fresh ideas are needed in the search for solid propellants with superior ballistic and processing properties; new propellant binders, adhesives, restrictors and other intermediates; analytical studies related to systems dynamics and stresses of missiles and propulsion systems; stress analyses related to pressure vessels, thrust structures, and associated components; and in the attainment of a solid propellant of good tensile strength and elongation over a wide temperature range.

Thus, there is exceptional opportunity today at Astrodyne for engineers, chemists, physicists, advanced designers, mathematicians, process and systems engineers, thermodynamicists, and many other engineering and scientific skills.

Remember that opportunity is composed of "good chance, favorable juncture of circumstances, and fit time." At Astrodyne the circumstances are favorable, the chances for employment and advancement are good, and the time is right. If you are interested in opportunity in the solid propellant field, write to Ralph Woodburn, chief of our Personnel section, Astrodyne, Inc., P. O. Box 548, McGregor, Texas.

John F. Tormey, Director
Engineering & Development

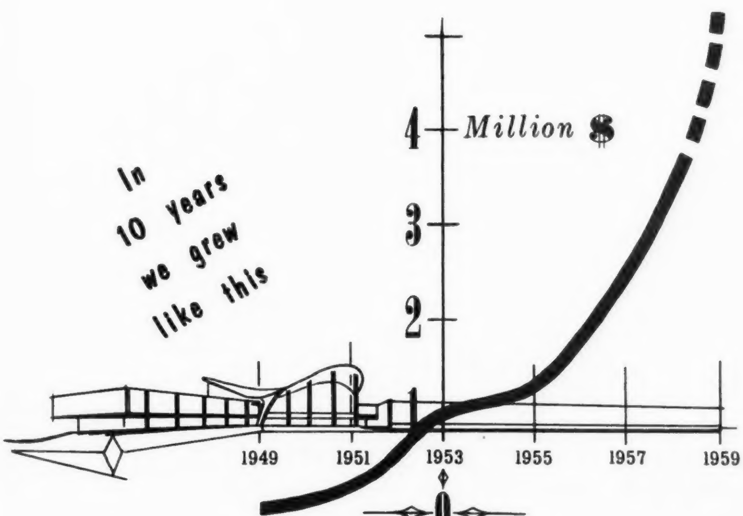


Astrodyne experimental area is focal point of advanced propellant development work at company's 12,000-acre facility in central Texas.

Atlantic Research Corporation

Alexandria, Va.

In the Metropolitan Washington, D. C., Area



Milestones of the Past Year

Started 20 new programs

Flight tests of the ARCON High Altitude Sounding Rocket at Wallops Island, Va.

Flight tests of the ARCAS Meteorological Rocket at White Sands, N. Mex.

Retro and Spin Rockets flown on Vanguard Satellite System

Vernier and Retro Rockets used on Pioneer Moon Probe

Built 5 new buildings at Pine Ridge Pilot Plant

Started project work for 27 new clients

Impact-absorbing foam plastic developed

Developed automatic telegraph transmission test equipment

Developed 2-man portable launcher for ARCAS rocket

Spray film developed for taking and preserving fingerprints

Initiated studies of electroluminescent transparent display media

ARC is • • •

A fast rising example of the space age's research industry, we have grown without outside financing and with profits every year. Advanced application of scientific and engineering knowledge has created new concepts, processes, and products serving some of the most ambitious programs of industry and government.

Human talent of high scientific competence has brought about significant contributions to such programs as **Thor, Atlas, Pioneer, Polaris, Vanguard, Terrier, Mercury, Sparrow,** and **Minuteman.** Outstanding careers have been created at an early age through work on these advanced projects. This same technical talent is developing our own upper air and research sounding rockets, **Arcas, Arcon,** and **Iris.**

The variety and number of contract research projects explain our stability. We are free of the feast-or-famine hazards of the immense systems project operation. We have *career* positions—not just in theory, but in practice.

Scope • • •

From a single small contract 10 years ago, our activities have multiplied to approximately 60 projects, currently encompassing:

- Rocket Engineering and Manufacture
- Solid Propellant Development
- Instrument Development
- Jet Propulsion Science
- Combustion Research
- Shock and Vibration
- Fluid Mechanics
- Optics
- High Temperature Experimentation
- Static Electricity in Fuel Systems
- Materials Development
- Polymer Science and Plastics
- Hardware Design and Fabrication
- Pyrotechnics Production and Development
- Interior and Exterior Ballistics

Our People • • • Our Future

From the 50 or more scientists and engineers who will join us in 1959, we will gain added resources to continue our growth. Technical imagination and depth are more important than age or experience in our staff expansion needs. We are actively seeking such people now. There is a place for you if you fit the pattern and are qualified to make a career of contributing to the creation of new technologies. Our future will be achieved by an enlarged staff of continued high scientific competence.

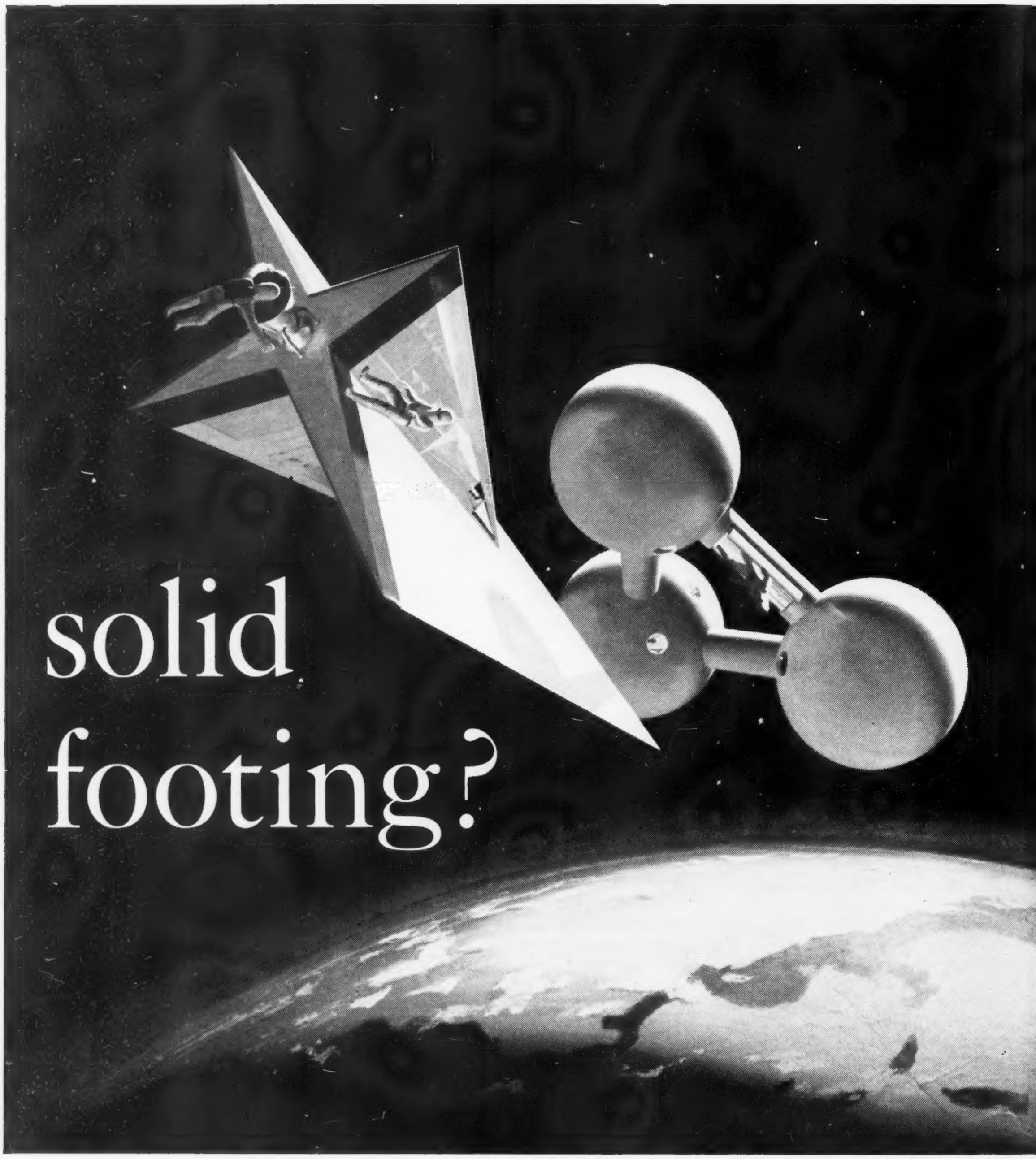
Your future has no limit in an environment where outstanding technical achievement is producing rapid growth. New projects are under way that offer exceptional opportunities for high technical capability in aerodynamics, materials engineering, propellant processing, physics, rocket project engineering, meteorological instrumentation, solid state phenomena, mechanical design, fluid mechanics, and polymer chemistry.

If your academic training is in the engineering or basic sciences, and you would like to determine where your abilities can contribute to our mutual growth, send complete résumé to:

Clarence H. Weissenstein, Director
Technical Personnel Recruitment
Atlantic Research Corporation
Alexandria, Virginia

A Dynamic Example of the Space Age Research Industry
(In the Washington, D.C., Metropolitan area)

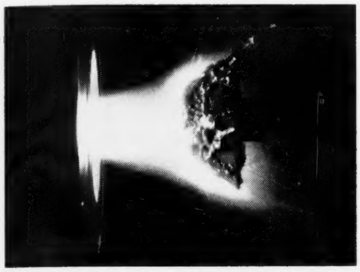
One Wing of Our New Headquarters Was Occupied in January. Full Operation Is Slated for Early Spring.


solid
footing?

Avco Research and Advanced Development Division

201 Lowell Street

Wilmington, Massachusetts



Plasma jet bathes missile model in flame of 20,000 degrees Fahrenheit for materials testing, aerothermodynamics, and ion propulsion study programs.

Research and development in physical hypervelocity installation at Avco RAD has included adaptation of Kerr cell techniques, shadowgraph and photography systems for recording aeroballistics experiments in the laboratory.

IN WILMINGTON, Mass., Avco has created a new center for work in applied sciences and advanced engineering. This complex of modern buildings houses the laboratories and administration of Avco Research and Advanced Development Division.

Avco RAD is the prime developer of the vital re-entry vehicle, or nose cone, for both the Air Force Titan and Minuteman intercontinental ballistic missiles. Research, development, engineering design, environmental testing, flight simulation, and prototype fabrication of this "business end" of the ICBM have led Avco into many related and varied fields of missile technology and space flight including:

- Aerophysics and aerochemistry
- High-temperature materials
- Electronics
- Field and re-entry communications
- Mathematics and computing
- Engineering and ground support
- Environmental testing
- Flight simulation and testing

Avco established itself as a pioneer in atmospheric re-entry as early as 1955.

The Avco Research Laboratory, a separate division at Everett, Mass., undertakes programs in re-entry physics, satellite studies, high-temperature gas dynamics, and magnetohydrodynamics.

The divisions' parent firm, Avco Manufacturing Corporation, is one of the hundred largest firms for industrial and defense operations in the United States. Twenty-six installations in 10 states and Canada offer 10,000,000 sq ft of productive floor space. Avco corporate operations during 1958 were divided among the production of aircraft engines and parts, electronics, aircraft and missile structures, farm equipment, radio and television broadcasting, and research and development.

Wilmington is a semi-rural suburb 15 miles northwest of Boston. In this location, Avco Research and Advanced Development Division is centrally situated among the great educational institutions and private and government laboratories of New England. Its 2200 employee strength includes a staff of 600 exceptionally qualified scientists and engineers. Information requests should be directed to the Personnel Relations Department, Avco RAD, 201 Lowell Street, Wilmington, Mass.

Aerial view of the $16,000,000 Avco Research Center, located on a 100-acre site in Wilmington, Mass., near Boston's "golden semicircle" Route 128.

Chrysler Corporation

Missile Division

Detroit, Michigan

MICHIGAN ORDNANCE MISSILE PLANT

THE Missile Division of Chrysler Corporation as prime contractor has cooperated with the U.S. Army in the engineering, development, and production of the Redstone and the Jupiter ballistic missile systems. The production and much of the development of both of these missile systems is accomplished at the Government owned, Chrysler operated Michigan Ordnance Missile Plant, located sixteen miles northeast of downtown Detroit. At this modern, one-story plant covering over two million square feet, approximately ten thousand employees combine their talents to produce two of the most reliable, deterrent weapons in the free world's arsenal.

In addition to the operations at the Michigan facility, research and development activities are carried on in Huntsville, Ala., where nearly one thousand Chrysler Missile Division employees provide engineering support and services for the Army Ballistic Missile Agency.

Recent developments in space technology have made it apparent that, as the fields of space exploration and ballistic missilery broaden in scope, the demands on industry to keep pace with the technological developments will increase proportionally. The Chrysler Missile Division is keeping pace with these demands and, through the know-how gained during the past six years, is providing the necessary development and production capabilities to meet new challenges of the space age.

In such an environment the recently graduated engineer as well as the experienced engineer will find unlimited opportunities for technical growth, job satisfaction, and career development with Chrysler Corporation Missile Division.

America's first operational ballistic missile—the Redstone—was developed by the Army at the Army Ballistic Missile Agency with the assistance of Chrysler engineers and personnel located at the Redstone Arsenal in Huntsville, Ala. It was a modified version of this Redstone that provided the first stage of the Jupiter C vehicle that successfully launched the United States' first space satellite—Explorer I—and then went on to put Explorer's III and IV in orbit within the following six months.

In December of 1957, Chrysler Corporation was named prime contractor for the development and production of the Jupiter missile system. The Jupiter is an Intermediate Range Ballistic Missile with a test-proved accuracy of over 1500 miles, and is currently being used as the first stage of the Juno II rocket in the National Aeronautics and Space Administration programs in the exploration of outer space.

JUPITER
Intermediate Range Ballistic Missile

FOR FURTHER INFORMATION

WRITE

CHRYSLER CORPORATION

MISSILE DIVISION

PERSONNEL DEPARTMENT 2201

BOX 2628

DETROIT 31, MICH.

THE FORWARD LOOK

Daniel, Mann, Johnson, & Mendenhall

3325 Wilshire Boulevard

Los Angeles 5, California

WE'RE working for tomorrow

Our past is filled with breadth of achievement. The depth of technical skill is readily apparent. Today, DMJM or "DIM JIM" as our firm is remembered is contributing greatly to our nation's true progress in defense and in industrial and civic growth.

Last year Architectural Forum rated the 100 largest Architectural and Engineering Firms. Daniel, Mann, Johnson, & Mendenhall rated third in size in the nation, having a record of almost 600 assignments totaling more than two and a half billion dollars of total costs. This sizeable amount has included the design of numerous Atlas, Thor, Jupiter and Titan test and launch complexes including both "hard" and "soft" based installations. Our IRBM work is being accomplished in places remote to the United States.

Design has been accomplished for major missile range facilities including NASA's Wallops Island.

DMJM's designs are varied and many including not only missile bases but also hotels, schools, dams, roads, harbors, office buildings, and airports, to name a few. Yes, our past consists of broad accomplishments made possible by the vision and abilities of our four hundred and fifty systems engineers, architects, physicists, mathematicians, civils, mechanicals, electronics engineers and numerous other professional engineering and design personnel.

Today the firm is actively designing highly sophisticated support systems and facilities. Electronic and mechanical systems design are accomplished and integrated with facilities design by the DMJM organization. Systems engineers working in a highly professional atmosphere with architects and other professional engineers are able to apply a broader perspective to projects.

An example of the integrated design approach is today's design for a Sonic Fatigue Test Laboratory being performed for ARDC. This facility will eventually represent a 7 million dollar investment to the Government.

This advanced Sonic Lab will solve some of the problems which have harried aircraft designers for years. What happens to the molecular structure of aircraft members when sound levels in proximity of the aircraft exceed 150 db? What happens when a nose cone re-enters the earth's atmosphere after static tests have shown that the material can normally withstand several thousand degrees. In another year these questions may become academic.

The Sonic Lab is a typical advanced engineering design program at DMJM. The main reverberation chamber will determine the effectiveness of noise generation. Since there are no parameters to go by the objective is to test materials at high intensity sound levels in a simulated aircraft or missile environment; instrument the specimen; dissipate heat; eliminate noise pickup; digitize information rapidly; X-ray and inspect the specimen. Determine when, why and how the structure fatigues.

That's today. Then there's tomorrow.

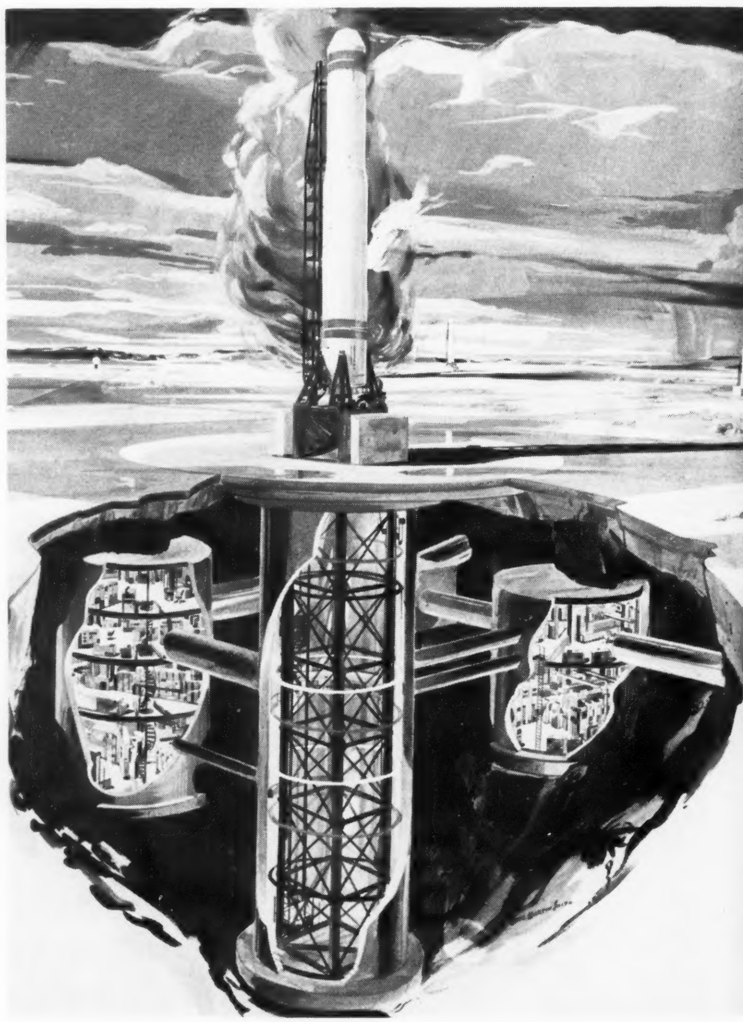
We at DMJM have dynamic long range plans. Plans with a future and a purpose that not only include state-of-the-art but also state of thought problems. To get there we've chosen our building blocks carefully. We've nursed a solid reputation and we're adding to it every day. Our record is our foundation. Yes, we've a plan for the future.

This plan is significant on two counts. One is the vehicle—the other the people. Of these we recognize the ultimate importance of the man. We choose him, cultivate him and encourage him.

The vehicle is our plan of combining allied arts and sciences. As an integrated architectural-engineering firm we cross breed the architectural arts and the scientific and engineering disciplines with socio-economic influences. The yield comes with changes in attitude, conceptual increases and the broadening of the man.

Our plan takes the best influences of each profession and extends them to the others. The architect is the classical planner and builder. The engineer, the literal do-er. The scientist, the theorist. Each uses his own language, his own process of development and arrives at his own conclusion. By influencing and broadening his thoughts he does it better, more effectively and to a degree not apparent before.

The path is open. DMJM's past is filled with achievement. The skills of our staff are sound. There is a future for you at DMJM — May we talk it over?



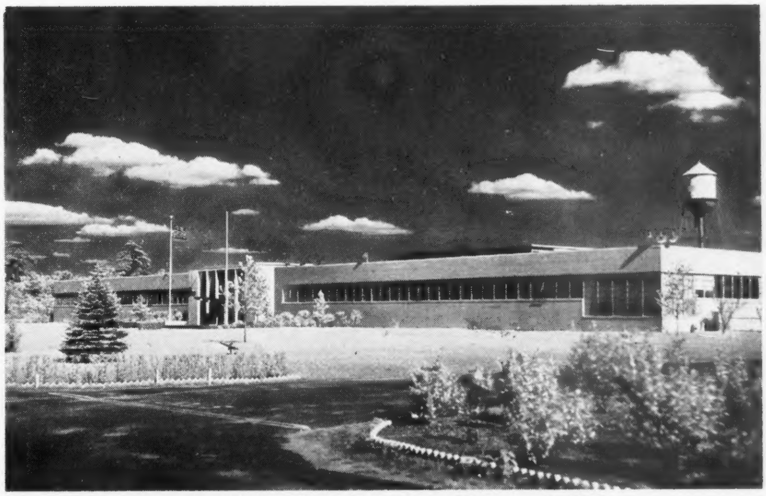
Fairchild Astrionics Division

A Division of

Fairchild Engine and Airplane Corporation

Wyandanch, Long Island, N. Y.

On December 1, 1958, the name of the Guided Missiles Division was changed to the Astrionics Division. This new name defines more clearly the Division's current activities in the missile and aircraft industry and its plans for work in space flight technology to support the objectives of the Fairchild Corporation.



Modern plant of the Fairchild Astrionics Division at Wyandanch, N.Y.

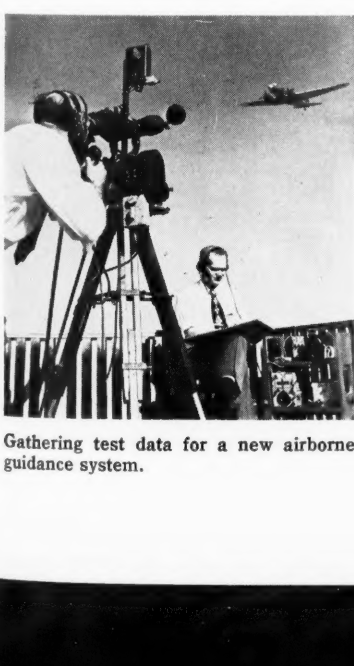
Background

FAIRCHILD Astrionics Division has long specialized in conceiving, designing, and producing missile systems. It has produced three complete missiles, numerous guidance sub-systems, a wide variety of components and special equipment, and has earned a reputation as a creative and efficient organization. The new mission of the Astrionics Division is to develop and produce guidance and control (astrionic) systems and related electronic devices for use with aircraft, guided missiles, or spacecraft.

The Astrionics Division is an autonomous division of Fairchild Engine and Airplane Corporation, Hagerstown, Md. As a member of this corporate family, the Division's skills and facilities are supported by the technical and financial resources of a large, diversified organization.

Activities

A wealth of experience and missile know-how has evolved from such early projects of the Division as the Lark, Gorgon, and Petrel, and from more recent astrionic projects which include the guidance, control, and data systems for military drones and decoy missiles.



Gathering test data for a new airborne guidance system.

In addition, the Division has had heavy systems experience in guidance and control, radar, trainers, simulators, etc. In most cases, it has designed and produced factory and field test equipment and ground equipment including launchers and units for guidance and control checks, pressure, hydraulic, power plant, supply and distribution testing, and checkout of auxiliary test equipment.

Engineering Teamwork

Engineering teamwork is a fact at Fairchild Astrionics Division. Engineers work together in small team units, seeing their project through from start to finish. Individual thinking speeds progress in such fields as midcourse guidance for spacecraft, surveillance systems, jet-reactive controls, and missile simulators.

Management is *by* engineers, *for* engineers—which fosters a professional atmosphere where engineers can make the most effective use of their creative abilities.

Ideal Location

Fairchild Astrionics Division, in the heart of Long Island, provides an unusually attractive working environment just a short distance from Manhattan. It is situated in an area rich in colleges and universities, and in housing and shopping facilities, boating, swimming, golfing, and many other recreational activities.

A Challenge

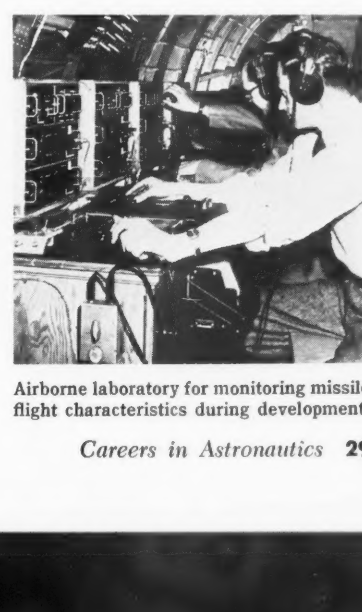
The Astrionics Division offers the ambitious scientist or engineer the challenge of complex, advanced projects, to which he can contribute his skills as part of a dynamic, expanding company. Your career opportunities are as unlimited as the future prospects of Fairchild Astrionics.

Your Future

Diversity of projects, stimulating assignments, professional advancement, and the personal satisfaction of accomplishment are offered at the Astrionics Division.

For additional information concerning your future at the Astrionics Division write to:

Mr. William Ziminski
Fairchild Astrionics Division
Wyandanch, Long Island, N. Y.



Airborne laboratory for monitoring missile flight characteristics during development.

Research and Development for the Seeking Mind

Instrumentation Laboratory

Massachusetts Institute of Technology

History •

With a history of pioneering and breaking through the horizons of scientific knowledge, the M. I. T. Instrumentation Laboratory is constantly striding forward into challenging research and development.

At the moment we are engaged in the research and development of inertial guidance systems and components for use in missiles and space vehicles of varied sorts. Under the direction of Dr. C. Stark Draper, the Laboratory has achieved fame for its outstanding contributions and leadership in the development of high performance control systems making use of an ultimate combination of gyroscopic devices—servomechanisms and electronic components.

Among the more publicized achievements of the Instrumentation Laboratory (remembering that a great deal of our work is classified) are the Navy Mark 14 Gunsight, the Air Force AI Gunsight, Hermetic Integrating Gyros (HIG), the Ship Inertial Navigation System (SINS) and, as early as 1953 and again in 1957, the flights from Boston to Los Angeles without a single reference by human eye, mechanical, or electronic device to the ground or stars. Present effort includes participation in Polaris and Atlas programs and other advanced systems for cis-lunar and interplanetary projects.

Work •

The Laboratory is primarily engaged in the conception and perfection of completely automatic control systems necessary for the flight and guidance of aircraft, missiles and other vehicles.

R and D opportunities exist in:

- **System Design & Theoretical Analysis**
- **Astronautics**
- **High Performance Servomechanisms**
- **Power Supplies**
- **Magnetic Amplifiers**
- **Analog and Digital Computers**
- **Electro-mechanical Components**
- **Transistor Circuitry**
- **Printed Circuitry**
- **Environmental Instrumentation & Evaluation**
- **Research, Design & Evaluation of Gyroscopic Instruments**
- **Computer Programming**
- **Simulator Studies**
- **Classical Mechanics**
- **Optical Instrumentation**
- **Pulse Circuitry**

and in many other areas.

Associates and Working Conditions •

The strength of the Instrumentation Laboratory lies in the caliber of its staff of 800 employees, dedicated to furthering the quest for advancement of the frontiers of scientific knowledge. The high standards of the professional staff and the magnitude and importance of its programs enable the Laboratory to assign to individual scientist and technical men a measure of responsibility much greater than the ordinary.

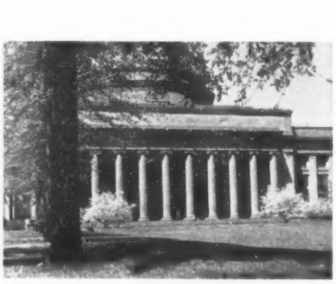
Educational Opportunities •

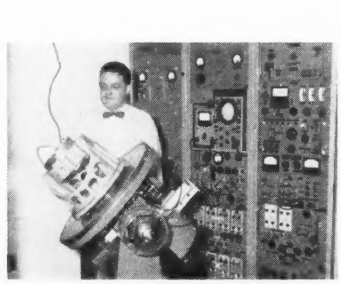
The atmosphere that prevails in Instrumentation Laboratory is both stimulating and congenial; academic and yet industrial. The opportunity for professional growth is implemented by an expanded graduate study program which encourages staff members to work toward advanced degrees as special students while earning full pay.

**Interested
Applied Physicists
and
Engineers . . .
Electrical,
Mechanical,
and
Aeronautical.**

**Write: Ivan R. Samuels, Dir. of Personnel
M.I.T. Instrumentation Laboratory
45 Osborne St., Cambridge 39, Massachusetts**

U. S. Citizenship required.



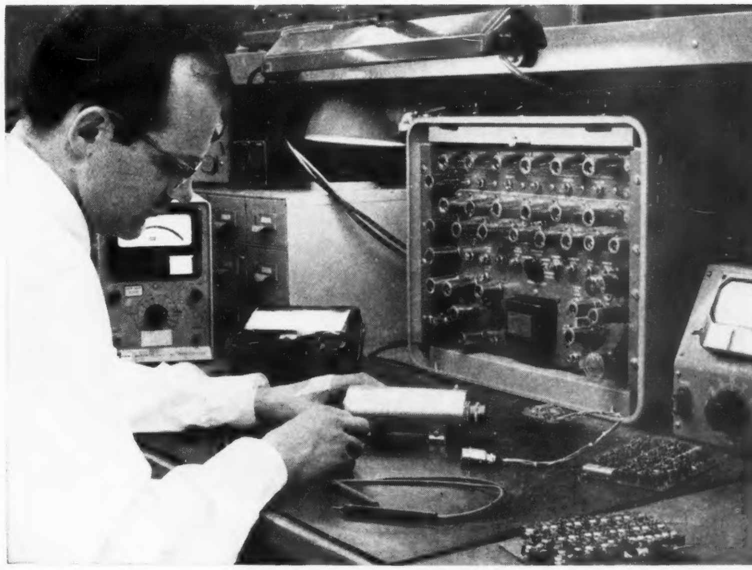


Lockheed Missiles and Space Division

Sunnyvale, California

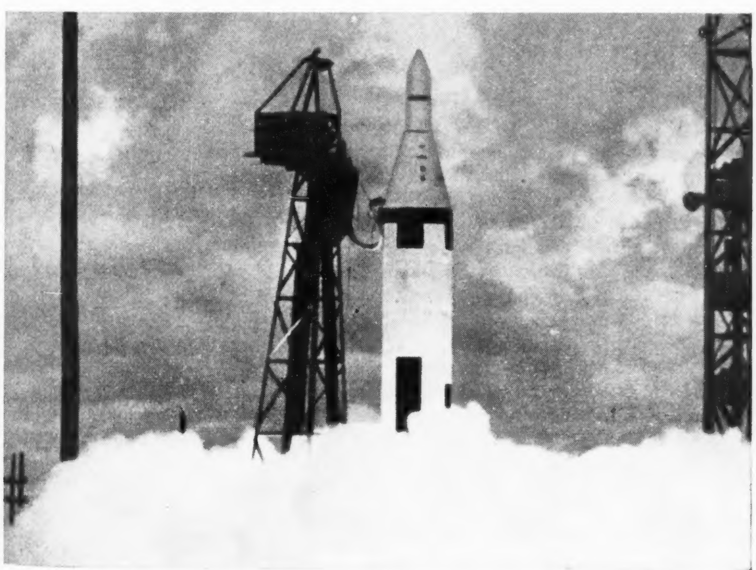
LOCKHEED is engaged in all areas of scientific activity in missile and space technology from concept to operation. These include more than 40 areas of research and development, engineering, test, and manufacture. As systems manager for such major, long-term projects as the Navy Polaris FBM, Army Kingfisher, Discoverer Satellite, Air Force Q-5 and X-7, the Division has established an enviable record of achievement. Tribute was paid to this record by Lockheed's industry associates at the first National Missile Industry Conference when the Division was honored as "The organization that contributed most in the past year to the advancement of the art of missiles and astronautics."

In addition to the projects, Lockheed is conducting important basic research and development in such fields as: advanced systems research; nucleonics; physics; chemistry; mathematics; metallurgy; design; test; electronics; magnetohydrodynamics; aerothermodynamics; ionic, nuclear, and solar propulsion; sonics; materials and processes; electromagnetic wave propagation and radiation; computer development; and operations research and analysis.



Monitoring the new air-borne 6" miniaturized TV camera, a Lockheed first in both the missile and television fields.

Headquarters for the Division are at Sunnyvale, California on the San Francisco Peninsula. Research and development facilities are located in the Stanford Industrial Park in nearby Palo Alto and at Van Nuys, California in the San Fernando Valley of Los Angeles. A 4,000 acre, company-owned test base in the Ben Lomond mountains 30 miles from Sunnyvale conducts all phases of static field testing. Together, the Division's facilities occupy more than two million, six hundred thousand square feet of laboratory, engineering, manufacturing and office space and provide the latest in technical equipment.



Navy Polaris AX-1 flight test vehicle at beginning of launch, Lockheed's Polaris fleet ballistic missile is more than a year ahead of original schedule.

Lockheed recognizes that its future progress and leadership are dependent on the scope and importance given to its research scientists and engineers today. The Division's programs reach far into the future. It is a rewarding future which men of outstanding talent and inquiring mind are invited to share.

Write: RESEARCH AND DEVELOPMENT STAFF, DEPT. D-82, 962 W. El Camino Real, Sunnyvale, Calif.

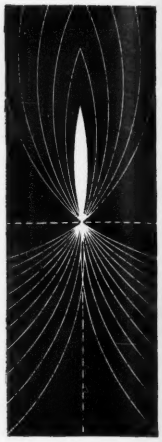
Lockheed

MISSILES AND SPACE DIVISION

Sunnyvale, Palo Alto, Van Nuys, Santa Cruz, Santa Maria, California
Cape Canaveral, Florida
Alamogordo, New Mexico

American Rocket Society Student Chapters

Academy of Aeronautics
Alabama Polytechnic Institute
Boston University
California State Polytechnic College
City College of New York
University of Colorado
University of Connecticut
Drexel Institute
Fairleigh Dickinson University
Fenn College
University of Florida
Georgia Institute of Technology
University of Hartford
Marquette University
Massachusetts Institute of Technology
University of Miami
University of Michigan
University of Minnesota
University of Missouri
Newark College of Engineering
New York University
University of Oklahoma
Parks College
Polytechnic Institute of Brooklyn
Stevens Institute of Technology
University of Texas
Tri-State College
Vanderbilt University
University of Virginia
University of Washington
Wayne State University



American Rocket Society

1959 Student Awards Competitions

For Undergraduate Students

$1000 ARS Chrysler Corporation Award to be presented to the undergraduate or team of undergraduates submitting the paper on any subject related to astronautics which is judged best by the ARS Awards Committee.

For Graduate Students

$1000 ARS Thiokol Chemical Corporation Award to be presented to the graduate student or team submitting the paper on any subject related to astronautics which is judged best by the ARS Awards Committee.

Previous Recipients

1956—James B. Blackmon, Cal. Tech.
1957—John Reece Roth, M.I.T.
1958—Thomas W. Godwin, Fenn College
Carl F. Lorenzo, Fenn College

Previous Recipient

1958—Frederick H. Reardon, Princeton

Appropriate subjects include:

- Flight Mechanics
- Guidance and Navigation
- Human Factors
- Hydromagnetics
- Hypersonics
- Ion and Plasma Propulsion
- Instrumentation
- Liquid Rockets
- Logistics and Operations
- Missiles and Space Vehicles
- Non-Propulsive Power
- Nuclear Propulsion
- Physics of the Atmosphere and Space
- Propellants and Combustion
- Ramjets
- Solid Rockets
- Space Communications
- Space Law and Sociology
- Structures and Materials
- Test Facilities and Support Equipment

Both awards will be presented at the ARS Honors Night Dinner at the Sheraton Park Hotel, Washington, D. C., November 18, 1959.

Deadline date for complete manuscripts: September 1, 1959.

All contestants *must* submit entry forms along with manuscripts. The forms contain complete details on eligibility and procedure for preparation of manuscript. They may be obtained by writing to the address below. Be sure to specify which of the two competitions you wish to enter.

1959 Student Awards Competitions

American Rocket Society

500 Fifth Avenue, New York 36, N. Y.